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TOXEMIC ANEMIA FROM ARSENIURETTED HYDROGEN GAS IN SUBMARINES*

SURGEON LIEUT. COMMANDER SHELDON F. DUDLEY, M.B., B.S. (LOND.), M.R.C.S. (ENG.)

Clinical Pathologist, Royal Naval Hospital, Portsmouth

ON June 15, 1916, three men from submarine D.4 were admitted to the Royal Naval Hospital, Chatham, as cases of poisoning by carbonic oxide or carbon dioxide. An examination of these men's blood showed they had suffered an enormous destruction of the red cells. This condition was obviously not due to carbonic oxide or carbon dioxide, but did suggest the presence of an extremely toxic gaseous poison in the air of the submarine. I therefore reported the condition found, submitted it would be advisable to search for the cause in the boat, and that other members of the crew should be examined to see if they were suffering from a similar condition. Clinically, the cases were those of poisoning by arseniuretted hydrogen gas, and the urine, hair, finger and toe nails of some of the cases contained arsenic.

Submarine D.4 did two trips in which symptoms occurred. The first trip started May 16, 1916; she was absent seven days, submerged seventeen hours daily, and returned to her base on May 24th. The second trip started on June 3d; she was only away four days when she had to return on June 8th; the average time she was submerged was also seventeen hours daily.

D.3 did three trips during which toxic symptoms developed. The first was in February, 1916, and lasted eight days, the boat being submerged about the same time as on the other trips. The second trip started on June 19th and ended June 27th,—eight days, with eighteen hours' diving a day. The third trip, commencing on July 21st and finishing on July 23d, was experimental in nature, as the commanding officer of the boat had orders to return if symptoms occurred. On his return the commanding officer stated that the first symptoms started at the eighth hour of the dive, the vomiting at the 14th hour, and at the 18th hour the submarine broke surface. Within twenty minutes, twenty of the crew of twenty-six had vomited, fresh hands and men who had been in the boat on the previous trips being equally affected. This third trip of D.3 conclusively proved the batteries to be the source of the gas. All the men I interrogated put their symptoms down to an evil smelling new fuel; but as this trip was undertaken with fresh fuel but with the same battery, the fuel must be exonerated from all blame. In addition, since D.3 has been fitted with new batteries she has dived without any untoward symptoms among the crew. In the first trips of both boats the symptoms were not so marked as in the second trips, and the crew were well enough to carry on duty or to proceed on leave on their return. The weather had been very bad and the vomiting was attributed to it, in spite of the fact that many men affected had been in the submarine service for years, and had never been seasick in their lives. (It should be noted that two men from D.3 were sent to the hospital after the first trip, but their condition was not diagnosed.)

In all, thirty cases have been admitted from these two boats, fifteen from each.

*Received for publication April 22, 1919.

With the exception of three cases (Nos. 16, 17, and 18), none were seen till five days or more had elapsed after the return of their submarine; hence, in making this report, one has to depend a good deal on the histories given by the men and on the hospital case sheets rather than on the signs and symptoms evident on admission. However, these submarine ratings, being doubly picked men of above average intelligence, gave very reliable accounts of what happened. I questioned and examined all the men myself, each man separately from the others, avoiding as far as possible any leading questions. The results of this examination are embodied in Tables 1 and 2, the cases being so similar that it would be tedious to describe each in detail.

In these tables each man is given a number and in the rest of the paper the cases are referred to by their numbers. The + sign means *symptom present;* ++, *symptom very marked;* —, *symptom absent.* In the column marked "Bowels," N means *regular or nothing unusual noted;* C, *constipation;* D, *diarrhea;* C→D, *constipation while in the boat, followed by diarrhea on return.* The last column shows the number of red cells per cubic millimeter and is entered as an index of the amount of anemia present. The blood changes, being the most interesting and the least studied characteristic of this toxemia, are treated in greater detail later.

Cases 1 to 15, in order of admission, came from D.4; the others from D.3, in order of admission. All the cases except the last three were admitted after the second trip of each boat; the last three came after the third trip of D.3.

TABLE 1

SUMMARY OF SYMPTOMS IN CASES FROM SUBMARINE D.4.

Number of Case	Date of Admission (1916)	Age	Temperature on Admission	Pulse Rate on Admission	Day of Onset of Symptoms: First Trip	Day of Onset of Symptoms: Second Trip	Vomiting	Pain in Abdomen	Bowels: N—As Usual, D—Diarrhea, C—Constipation	Dyspnea	Respiration Rate on Admission	Color of Urine as Described by Patient	Albuminuria, if Present Any Time After Admission	Edema of Face	Headache	Tingling of Hands and Feet	Jaundice	Millions of Red Cells per C. Mm.	Remarks
1	6/15	28	98.0	84	3	2	++	+	N	++	?	Very dark	+	−	++	++	+	2.56	Shooting pains in calves: insomnia after admission
2	6/15	36	98.6	80	5	....	+	−	C	+		Dark brown	+	+	+	+	+	1.78	Lowest blood count, but symptoms very slight on the trips: only vomited once in the boat
3	6/15	23	99.0	88	5	2	+	+	C	++	?	Dark red	+	−	+	+	+	2.25	On July 5th, had an attack of dyspnea and vomiting in hospital; had been well the day before and was well next day
4	6/20	23	97.6	68	5	1	+	−	N	+	18	Port wine	−	−	−	+	+	2.23	Had no complaint except a little lassitude after return: jaundice was very marked and bile present in urine
5	6/20	27	98.4	?	4	1	+	+	N	+	?	Golden syrup	+	−	+	++	+	3.74	Frequency and scalding on micturition
6	6/20	34	99.0	76	NS	1	+	−	N	+	24	Dark red	−	−	−	+	+	2.10	Running of the eyes, and dryness of throat; felt quite well during first trip
7	6/20	29	98.4	70	NS	7	−	−	D	−	20	Brown	+	+	+	+	+	3.49	No symptoms at all until last day of second trip
8	6/20	28	98.4	68	NS	2	+	−	N	+	20	Dark red	−	−	−	+	+	3.33	No symptoms on first trip
9	6/20	22	98.4	56	3	1	++	++	C→D	+	22	Red	+	+	−	++	+	2.90	Very acute burning pain in upper abdomen during the trip
10	6/21	36	98.4	80	NS	NS	−	−	N	−	?	Strong tea	−	−	−	+	+	3.65	No symptoms except headache and lassitude: herpetic eruption developed on backs of his hands; easily cured
11	6/21	23	98.4	72	4	1	+	++	C→D	++	18	Claret	+	−	−	+	+	4.28	Only vomited once: shooting pains in the legs after return
12	6/21	24	99.0	100	6	1	++	++	C	−	?	Port wine	+	−	+	−	+	4.55	Pain in abdomen very acute during the trips
13	6/21	27	98.4	80	....	1	++	−	C→D	++	?	Blood red	+	+	−	+	+	3.14	Only in boat during second trip
14	6/24	22	98.4	66	3	1	++	++	C	++	20	Blood red	+	+	++	+	+	3.83	Continual salivation during trip: troublesome insomnia on return
15	6/24	22	97.8	72	4	2	+	−	N	+	20	Brown	+	+	+	+	+	3.73	Legs gave out in a race on leave after trip

A study of this table shows that there was little difference in the degree of toxemia suffered in the two boats. D.3 produced the worst cases when admitted, but on the whole the D.3 cases arrived earlier than those from D.4. Urinary symptoms, swelling of the face, and albuminuria appear to have been more marked in the men from D.3, and the three patients who took longest to get a blood approaching the normal came from her. This difference may well have been due to the fact that the second trip of D.3 was just twice

the duration of that of D.4. D.3's last trip, only an eighteen hour dive, apparently produced the most rapid onset of symptoms. As stated above, twenty out of twenty-six in the crew were affected to the point of vomiting, and it is fair to conclude that this trip, if continued, would have produced still more severe, if not fatal, cases. The history of onset points to D.3, at least in the first trip, as having the more poisonous atmosphere, since symptoms started in D.3's crew on the first or second day, whereas in D.4 the onset of symptoms on the first trip was delayed to the fourth or fifth day, and some men escaped without symptoms at all. Both second trips were worse than the first, symptoms starting from the first dive.

TABLE 2

SUMMARY OF SYMPTOMS IN CASES FROM SUBMARINE D.3

Number of Case	Date of Admission (1916)	Age	Temperature on Admission	Pulse Rate on Admission	Day of Onset of Symptoms		Vomiting	Pain in Abdomen	Bowels: N—As Usual, D—Diarrhea, C—Constipation	Dyspnea	Respiration Rate on Admission	Color of Urine as Described by Patient	Albuminuria, if Present Any Time After Admission	Edema of Face	Headache	Tingling of Hands and Feet	Jaundice	Millions of Red Cells per C. Mm.	Remarks
					First Trip	Second Trip													
16	6/29	25	98.0	104	5	3	+	−	C→D	+	20	Mahogany	+	+	+	+	+	2.91	Scalding and frequency of micturition: had an attack of vomiting three days after admission
17	6/29	29	98.6	112	2	1	+	+	C	+	22	Tea color	++	+	+	+	+	2.72	Most marked and persistent albuminuria of any case
18	6/29	34	98.8	108	2	1	+	+	C	++	24	Port wine	+	+	+	++	+	1.98	Chief complaint, great thirst and burning of throat: blood showed more degenerative changes than any other
19	7/1	24	99.4	84	....	1	++	−	C	++	24	Very dark	+	−	+	−	+	2.60	Only did second trip: dryness of throat marked symptom
20	7/1	30	98.4	80	1	1	++	++	C	−	?	Port wine	+	++	++	+	+	3.51	Insomnia and fine tremor on admission: scalding and frequency of micturition
21	7/1	23	98.8	80	2	2	+	+	C→D	+	20	Dark brown	+	−	+	+	+	3.24	All symptoms mild
22	7/1	23	99.0	88	NS	4	−	−	N	+	20	Brown	+	+	++	+	+	2.86	Insomnia on return: burning and dry throat
23	7/1	24	97.6	84	4	1	+	++	C	+	20	Red brown	+	+	++	+	+	2.79	Pain in joints, and neuralgia of testes on return
24	7/1	26	98.6	88	5	1	++	−	N→D	+	18	Reddish	+	++	−	+	+	4.03	Swelling of face noticeable, and pain down right arm after admission
25	7/1	22	99.2	92	2	1	++	++	C	+	24	Port wine	+	−	++	+	+	3.13	Dryness of the mouth, and shooting pains in the legs on return
26	7/7	35	98.0	72	2	2	+	−	C→D	−	?	Never noticed	+	+	−	++	+	3.94	Melena on return (?): cramps and spasms in left arm, pains in thighs and legs: insomnia troublesome
27	7/7	38	99.2	84	3	2	+	−	N	+	?	Reddish	+	−	+	−	+	2.68	Had a shivering fit (no definite rigor) on admission to hospital after expiration of leave
28	7/28	24	99.2	84	Third trip only		+	−	N	−	?	Port wine	−	−	−	−	+	3.59	Only did third trip
29	7/28	30	98.6	90	3	3	+	−	N	+	?	Mahogany	+	+	+	+	+	4.13	Did all three trips: slight symptoms on first two, symptoms worst during the third trip
30	7/28	35	98.4	104	NS	NS	+	+	C	−	?	Strong tea	+	−	+	+	+	4.11	Only vomited after breaking surface on third trip

SYMPTOMS

Temperature and Pulse Rate.—The temperature of the patients was nearly always normal on admission. The pulse rate showed a tendency to be raised, especially in those cases seen earliest (e.g., Nos. 16, 17, 18). Notes on the hospital case sheets showed that most cases had a pulse rate of over 100 when first seen after return. One or two men had soft systolic *bruits* on admission. The pulse and heart conditions, however, were obviously only secondary to the anemia, and both settled down in a very short time to within absolutely normal limits.

Dyspnea.—Dyspnea, especially on exertion, was a very general symptom, only seven ratings saying that they did not notice it. In a few men it was the chief complaint, and this symptom was still evident in the majority of cases on admission. The dyspnea was evidently entirely due to the anemia, as no case showed any physical signs or symptoms of damage to the lung—a rather strange fact as the gas must have entered through the respiratory epithelium. In seventeen men, whose respiration rate was taken shortly after admission, while lying quietly in bed, the rate varied between 18 and 24 per min-

ute, showing a very slight rise above the normal.

Vomiting.—Vomiting was a constant feature; with most men it was continuous throughout the trip, but a few were only sick once or twice, and three men escaped this symptom altogether. The vomiting was accompanied in some cases by burning and griping pains in the upper abdomen, and by dryness and burning sensations in the throat. Fourteen of the cases admitted complained of pain in the abdomen, and in one or two ratings it was very acute indeed.

Constipation.—There is little to note about the bowels during the actual trips. Constipation was most generally complained of, but as likely as not it was due to the fact that the majority of the crew had no fancy for food and could keep nothing down. Eight patients, though constipated during the trip, had two or three days of mild diarrhea on return. Case 26 volunteered the statement that he passed a motion containing blood the day after he got back to Harwich.

Urinary Findings.—All ratings, with the exception of one man who did not notice it, were surprised by the color of their urine. The color was variously described as brown to blood red. (It should be remarked that some men, when possible, only micturated at night on the submarine breaking surface, so had little opportunity of seeing their urine while at sea.) The color was, in most cases, probably due to blood or its pigments, but for reasons discussed later in this paper, may in some cases have been due to bile only. Some men who complained of no other symptoms, passed dark urine on the first trip. The history given by the men who remembered the point, was that the urine became dark the day after the onset of symptoms, and remained dark till their return, when it became the ordinary color in two or three days. This hemoglobinuria certainly passed off very rapidly, as a most careful examination at the time of admission to the hospital failed to reveal any blood or pigments in the urine, either by microscopic, spectroscopic, or chemical methods. All urines, except those of Cases 16, 17 and 18 which contained obvious bile, were within normal color limits on admission. Besides the above three exceptions, the urine in four other cases gave a trace of bile by the iodine test, but not by Gmelin's nitric acid test. Case 28, however, throws light on the nature of the color of the urine and the reason of the failure to find a cause for it after admission. Fleet Surgeon O'Malley, to whom I am indebted for much useful information, states on the hospital case sheet of this man: "He returned in Submarine D.3 on 23d of July, this being his first voyage and first dive in a submarine. About the 12th hour submerged, he had headache and nausea and vomited a few hours later. He states his urine then was the ordinary color, and it was found to be normal in color and free from albumen when examined at 3 P. M. on the 23d inst.; but late that evening he passed a dark port wine colored urine containing albumen and blood;—Dr. Haldane found that this urine contained Haemoglobin and Methaemoglobin. The patient developed a slight yellow tinting of the conjunctivae on 25th July and his urine is now quite clear and free from albumen." (Dated July 28, 1916.) In this case, therefore, we have absolute proof that the urine contained blood and was absolutely normal four days after return.

Albuminuria was present at one time or another in all cases except three. This albuminuria was measurable in amount only on two occasions, both in Case 17. There was no difference in the morning and evening specimens of urine. In some cases albuminuria was absent on admission, appeared, cleared up, and reappeared in a most peculiar way. Table 3 contains three examples illustrating what is meant, and also includes the one case with persistent albuminuria. The specific gravity was roughly always normal, as was the amount passed in twenty-four hours in all cases where it was measured. The albumin was present only in traces.

The urine of Case 17 contained generally a few epithelial cells and one or two epithelial casts were found on the occasion when the albumin was at its highest. An epithelial cast was once found in the urine of Case 12; otherwise, in spite of careful hunting, no casts were ever found, though epithelium and leucocytes were often present in small numbers. Sugar, acetone, or other abnormal constituents of the urine were never detected. Bile,

TABLE 3

ALBUMINURIA IN CASES OF POISONING BY ARSENIURETTED HYDROGEN

Case 12		Case 2		Case 17		Case 18	
Date (1916)	Albumin	Date (1916)	Albumin	Date (1916)	Albumin	Date (1916)	Albumin
15/6 to 21/6	Nil	21/6	Nil	2/7 to 18/7	FT to T	2/7 to 11/7	Traces
5/7	FT	7/7	FT	19/7	0.05%	12/7	Nil
6/7	VFT	7/7	VFT	21/7	T	14/7	Nil
7/7	Nil	8/7	Nil	22/7	0.1%	15/7	T
9/7	Nil	12/7	Nil	23/7	Under 0.05%	19/7	Nil
10/7	VFT	2/8	FT	24/7	T	21/7	VFT
12/7	Nil	3/8	VFT	30/7 to discharge	Faint trace persists	23/7 to discharge	Nil
13/7	FT	5/8	T				
2/8 to discharge	Nil	6/8	VFT				
		8/8 to discharge	Nil				

VFT = Very faint trace on boiling.
FT = Obvious cloud.
T = Heavy cloud, under 0.05 per cent.

as mentioned above, was present in the admission urines of seven cases.

Edema.—Edema of the face and eyelids was not obvious in any case on admission, but the men were very certain that it had existed, and their messmates and the captain of D.3 noticed it and told me about it without any prompting, so I think there is no doubt that it did exist. It will be noticed that all the patients who gave a history of swelling of the face had albuminuria as well. There was no history in any case of swelling of the feet and ankles. I think this edema was undoubtedly due to a toxic nephritis, helped a bit by the concurrent anemia. Scalding and frequency of micturition, an out-of-the-way complaint of Cases 5 and 16, was probably caused by irritation of the bladder and urethral mucous membranes by arsenic. Though one or two other patients said that they passed urine more frequently, none except the above two complained of any scalding.

Conjunctivitis.—The metal, arsenic, is well known to cause irritation to any mucous membrane, and as some of the men complained of irritation and redness of the eyes, it seems as if the conjunctiva did not escape in all cases. This conjunctival irritation was probably caused by the arsenic brought by the blood stream, rather than by the direct action of what must have been a remarkably small amount of actual arseniuretted hydrogen in the air of the boats.

Headache and Insomnia.—Headache was a fairly constant symptom, and was persistent for some time after admission in many cases; it was very acute during the trip in some men, though many escaped it altogether. Insomnia which persisted for a week or two was troublesome in one or two of the ratings. The headache and insomnia may well have been secondary to the nephritis.

Neuritis.—Neuritic symptoms were present in every case except four. Of these four it is interesting to note that two had only done one trip, one of whom —the case quoted at length—had only been exposed to the gas for a day. This suggests that a considerable amount of gas had to be absorbed to produce any signs of neuritis. These symptoms did not, in the majority of cases, manifest their presence till three or four days after return from the voyage, but took two or three weeks to pass off. The neuritic symptoms consisted of vague tingling, numbness, "pins and needles" sensation in the hands and feet. The legs were prone "to go to sleep" easily, and a few men got cramps in the arms and legs at times. Some ratings also had various vague or shooting pains in the limbs, back, and joints. Another interesting point is that about half the men complained of toothache or facial neuralgia, and asked to see the dentist; and in one or two cases the dental surgeon reported no evident carious teeth. No objective nervous signs were present;

the knee jerks and other reflexes were normal, perhaps a little brisker than usual in a few men. There was no anesthesia detected.

Patient 15 described a peculiar thing that happened to him on leave. Feeling perfectly well, he went in at some sports for a 200-yard race but his legs suddenly "gave out" and he had to go to bed for two days with pain and tenderness of his calf muscles; he was, however, quite well within a week. I am at a loss to explain this attack, but it seems to have been a definite peripheral neuritis brought on by over-exertion in a man whose nerves had not properly recovered from an arsenical toxemia.

As an example of how a man was able to take exceptional exercise without bad results, I quote Patient 6 who was a keen long distance swimmer. He had been swimming nearly every day of his leave, and the day before he returned had swum over three miles and felt none the worse for it, either in wind or limb, and this a man who had had dyspnea, neuritic symptoms, and a count of only 2,100,000 red cells on admission.

Jaundice.—Jaundice was an absolutely constant sign. It was evident as a slight tinting of the skin and conjunctivae in most cases on admission, and all cases gave a history of it. The color never seems to have been very deep, but was always present. How noticeable it was, is shown by the fact that the men in other boats and adjacent ships referred to D.3 on her return as the submarine with the "Chinese crew." Bile was present in the blood serum and urine in a few cases, and there was no lack of bile in the feces. The jaundice passed off in about a week.

Before leaving the general symptoms to discuss the blood, it is worth noting that the degree of anemia present as indexed by the red count bore no direct relation to the acuteness of other symptoms.

For example, Patient 2 with the lowest

TABLE 4

BLOOD FINDINGS IN CASES OF ARSENIURETTED HYDROGEN POISONING

Reference No. of Case*	Complete Blood Count on Admission										Blood Count One Week After Admission										Blood Count Two Weeks After Admission										Reference No. of Case
	Date of Count (1916)	Millions of Red Cells per C. Mm.	Hundreds of White Cells per C. Mm.	Hemoglobin per Cent.	Color Index	Differential Leucocyte Count					Date of Count (1916)	Millions of Red Cells per C. Mm.	Hundreds of White Cells per C. Mm.	Hemoglobin per Cent.	Color Index	Differential Leucocyte Count					Date of Count (1916)	Millions of Red Cells per C. Mm.	Hundreds of White Cells per C. Mm.	Hemoglobin per Cent.	Color Index	Differential Leucocyte Count					
						Polymorphonuclear Cells	Small Mononuclear Cells	Large Mononuclear Cells	Eosinophile Leucocytes	Basophile Leucocytes						Polymorphonuclear Cells	Small Mononuclear Cells	Large Mononuclear Cells	Eosinophile Leucocytes	Basophile Leucocytes						Polymorphonuclear Cells	Small Mononuclear Cells	Large Mononuclear Cells	Eosinophile Leucocytes	Basophile Leucocytes	
1	16/6	2.56	70	55	1.1	52.7	39.0	6.0	1.7	0.6	23/6	2.52	42	52	1.0	41.0	53.0	5.0	0.4	0.3	30/6	3.68	56	65	0.88	23.7	71.3	4.0	1.0	0.0	1
2	16/6	1.78	60	50	1.3	63.0	31.7	4.6	0.7	0.0	23/6	2.30	36	48	1.1	51.3	45.7	2.0	1.0	0.0	30/6	3.58	54	65	0.90	54.3	41.7	3.0	1.0	0.0	2
3	16/6	2.55	86	50	1.0	64.7	30.3	4.7	0.3	0.0	23/6	3.00	56	58	1.0	34.0	55.0	7.7	3.0	0.3	30/6	3.88	82	68	0.87	29.0	65.3	2.7	3.0	0.0	3
4	20/6	2.23	56	50	1.2	49.7	48.0	1.7	0.6	0.0	28/6	3.54	34	62	0.88	35.0	56.4	7.0	1.3	0.3	4/7	4.07	44	70	0.87	52.0	40.7	5.3	1.3	0.7	4
5	20/6	3.74	58	65	0.87	65.3	27.0	5.0	2.0	0.7	28/6	4.36	48	68	0.77	66.3	30.9	2.3	0.7	0.0	4/7	4.59	72	72	0.78	69.7	24.3	4.0	2.0	0.0	5
6	21/6	2.10	42	55	1.3	41.0	47.7	5.3	5.0	1.0	29/6	3.64	52	60	1.1	33.7	55.7	6.7	2.7	1.2	6/7	3.94	52	70	0.90	57.7	35.0	4.0	3.3	0.0	6
7	21/6	3.49	68	55	0.80	60.3	30.7	6.0	2.3	0.7	30/6	4.00	56	70	0.88	53.2	39.7	3.7	2.7	0.7	7/7	4.18	76	68	0.81	61.0	32.0	3.7	3.3	0.0	7
8	21/6	3.33	44	60	0.90	60.4	31.3	6.3	1.0	1.0	28/6	3.06	76	58	0.85	35.7	59.7	2.7	1.7	0.2	5/7	3.36	72	68	1.00	58.0	37.0	2.7	2.3	0.0	8
9	21/6	2.90	60	53	0.90	47.0	47.7	3.7	1.3	0.3	29/6	3.00	62	60	0.10	54.3	34.7	9.7	1.3	0.0	6/7	4.53	44	70	0.77	55.0	36.0	6.3	2.7	0.0	9
10	21/6	3.65	42	55	0.76	43.0	51.7	4.7	0.3	0.3	28/6	4.06	74	62	0.77	31.3	63.7	5.0	0.0	0.0	5/7	4.50	66	75	0.84	55.7	36.0	6.0	2.3	0.0	10
11	21/6	4.28	68	70	0.81	36.0	59.3	4.3	0.4	0.0	29/6	4.80	102	75	0.78	61.3	33.3	2.8	1.3	1.3	5/7	4.97	70	75	0.78	50.0	40.7	6.0	2.7	0.6	11
12	21/6	4.55	88	72	0.80	66.3	30.0	3.0	0.7	0.0	29/6	4.04	110	65	0.81	64.0	31.3	3.3	0.7	0.7	5/7	4.16	88	70	0.83	78.7	16.0	3.7	1.6	0.0	12
13	21/6	3.14	60	60	1.00	38.0	59.3	1.7	1.0	0.0	30/6	3.89	128	68	0.87	74.0	19.7	6.0	0.3	0.0	7/7	4.70	92	72	0.77	52.0	45.3	2.0	0.7	0.0	13
14	26/6	2.75	58	60	1.10	45.0	46.7	5.0	3.0	0.3	2/7	3.87	50	65	0.83	33.3	58.0	5.3	2.0	1.4	11/7	4.14	80	68	0.83	57.3	36.0	5.7	1.0	0.0	14
15	26/6	3.73	38	68	0.90	37.7	57.0	4.7	0.6	0.0	3/7	4.18	84	75	0.82	62.6	29.4	6.0	2.0	0.0	10/7	4.45	44	72	0.80	51.7	41.7	4.0	2.6	0.0	15
16	29/6	2.91	56	60	1.00	60.0	33.3	6.0	0.7	0.0	6/7	2.96	60	65	1.08	63.0	29.3	5.7	1.7	0.3	13/7	3.58	52	70	0.97	40.3	49.0	5.0	4.0	1.7	16
17	29/6	2.72	52	65	1.20	53.0	34.7	9.0	2.7	0.7	6/7	3.96	56	68	0.85	57.4	38.0	2.3	2.3	0.0	13/7	3.86	36	68	0.87	42.0	46.7	8.7	2.6	0.0	17
18	29/6	1.98	66	48	1.20	75.7	21.0	2.3	0.7	0.3	6/7	2.76	52	62	1.11	33.7	61.7	4.0	0.3	0.3	13/7	2.91	56	65	1.10	25.3	65.3	7.0	2.4	0.0	18
19	2/7	2.60	76	58	1.10	56.0	34.7	4.3	4.7	0.3	9/7	3.12	60	62	1.00	47.0	47.7	1.3	3.3	0.7	16/7	4.07	42	70	0.85	51.0	40.7	6.7	1.3	0.3	19
20	1/7	3.51	46	50	0.71	69.0	25.0	3.2	2.0	0.7	9/7	3.84	30	62	0.81	44.0	43.3	8.0	3.7	1.0	16/7	3.91	52	72	0.92	71.0	21.7	5.0	2.3	0.0	20
21	1/7	3.24	38	55	0.86	52.7	42.3	1.3	3.7	0.0	9/7	3.58	56	60	0.83	43.3	43.3	5.7	6.7	1.0	15/7	4.16	54	68	0.81	40.0	49.0	6.3	3.3	1.4	21
22	1/7	2.86	70	52	0.89	36.0	53.3	4.7	6.0	0.0	9/7	3.41	56	62	0.91	37.7	51.0	4.3	6.3	0.7	15/7	4.44	46	68	0.77	64.0	34.3	3.0	1.7	0.0	22
23	2/7	2.79	54	48	0.89	64.0	30.7	3.7	1.6	0.0	9/7	3.36	40	58	0.85	32.0	60.3	4.0	3.7	0.0	24/7	4.02	64	65	0.81	55.0	35.0	7.0	2.7	0.3	23
24	2/7	4.03	70	65	0.81	66.7	23.7	2.6	7.0	0.0	9/7	3.54	42	60	0.86	50.3	35.3	4.3	9.3	0.8	16/7	4.02	48	70	0.87	71.5	17.0	5.5	5.3	1.4	24
25	2/7	3.13	64	60	0.97	57.7	38.3	2.3	1.7	0.0	10/7	3.90	60	70	0.90	35.7	54.7	4.0	5.0	0.6	16/7	3.76	64	72	0.95	57.7	33.3	4.7	2.3	2.0	25
26	8/7	3.94	46	62	0.82	40.7	52.7	3.0	3.0	0.6	15/7	4.35	50	68	0.77	46.7	44.7	6.0	2.6	0.0	22/7	4.37	70	75	0.83	72.0	22.7	3.3	2.0	0.0	26
27	8/7	2.68	50	58	1.10	42.0	47.3	10.0	0.0	0.7	15/7	2.85	46	60	1.0	58.0	26.7	14.0	1.0	0.3	22/7	3.09	36	68	1.10	54.7	37.0	6.0	1.3	1.0	27
28	30/7	3.59	42	65	0.90	47.3	46.0	3.7	3.0	0.0	9/8	3.51	62	78	1.10	57.0	34.7	5.7	2.6	0.0	17/8	4.70	56	72	0.77	62.0	27.0	5.5	5.5	0.0	28
29	30/7	4.13	54	65	0.79	47.3	37.3	6.4	9.0	0.0	9/8	4.19	86	75	0.89	61.4	29.3	3.0	6.3	0.0	17/8	4.34	48	75	0.87	46.7	30.7	7.6	14.0	1.0	29
30	30/7	4.11	46	62	0.75	42.7	51.3	4.0	1.3	0.7	9/8	3.94	82	72	1.10	42.3	50.7	3.7	3.3	0.0	17/8	4.34	48	75	0.87	56.0	33.0	8.0	2.0	1.0	30

*Cases 1 to 15 are from D.4: Cases 16 to 30, from D.3.

number of red cells protested he was as fit as any man in the boat till the last day of the trip, whereas Patient 14 with little diminution of his red corpuscles had most severe general symptoms, acute pains in the head and abdomen, and continuous vomiting.

THE BLOOD

The Red, White, and Differential Counts

I investigated the blood in this condition as carefully as possible, since I can find little about the finer blood changes in the literature of the subject. Nearly 200 complete counts and hemoglobin estimations were made, besides many other observations; the majority of the counts are enumerated in Tables 4 and 5.

Red Blood Cells.—The erythrocytes on admission were reduced below 5,000,000 per c.mm. in every case; two cases had a count of under 2,000,000; in twelve cases the count was between 2 and 3,000,000; in 10 cases it was between 3 and 4,000,000; and in the remaining 6 men the number of red cells per c.mm. was over 4,000,000. The lowest count on admission was 1,780,000, the highest 4,550,000; thus the variation was considerable. The number of red cells increased very rapidly for the first fortnight, when the rate of increase slowed down. One week after admission only five men had a count under 3,000,000, and after a fortnight only one was below this number, while ten showed counts between 3 and 4,000,000. Three weeks after admission eight counts still were below 4,000,000 though not much below it, and at the end of the month only one patient (Case 1) had failed to reach 4,000,000 red cells per c.mm.

By the time the blood had reached 4,000,000, the patients were all feeling quite well and were given fourteen days' leave, on the expiration of which they returned to the hospital for further counts and observation.

The red cells in this last count were all

TABLE 5

BLOOD FINDINGS IN CASES OF ARSENIURETTED HYDROGEN POISONING (*Continued*)

Reference No. of Case*	Blood Count Three Weeks After Admission										Blood Count Four to Five Weeks After Admission, on Discharge to Leave										Last Blood Count After Return from Leave, Before Discharge to Duty										Reference No. of Case
	Date of Count (1916)	Millions of Red Cells per C. Mm.	Hundreds of White Cells per C. Mm.	Hemoglobin per Cent.	Color Index	Differential Leucocyte Count					Date of Count (1916)	Millions of Red Cells per C. Mm.	Hundreds of White Cells per C. Mm.	Hemoglobin per Cent.	Color Index	Differential Leucocyte Count					Date of Count (1916)	Millions of Red Cells per C. Mm.	Hundreds of White Cells per C. Mm.	Hemoglobin per Cent.	Color Index	Differential Leucocyte Count					
						Polymorphonuclear Cells	Small Mononuclear Cells	Large Mononuclear Cells	Eosinophile Leucocytes	Basophile Leucocytes						Polymorphonuclear Cells	Small Mononuclear Cells	Large Mononuclear Cells	Eosinophile Leucocytes	Basophile Leucocytes						Polymorphonuclear Cells	Small Mononuclear Cells	Large Mononuclear Cells	Eosinophile Leucocytes	Basophile Leucocytes	
1	7/7	3.78	60	70	0.90	35.7	60.0	4.0	0.3	0.0	14/7	3.95	64	70	0.87	45.0	39.0	8.7	5.3	2.0	1/8	4.66	64	82	0.89	51.7	33.3	10.7	6.0	0.3	1
2	7/7	3.93	60	68	0.87	58.4	36.3	5.3	0.0	0.0	14/7	4.04	60	72	0.90	68.0	26.7	4.7	0.3	0.3	1/8	4.47	52	78	0.87	53.7	38.3	7.0	1.0	0.0	2
3	7/7	3.98	80	70	0.87	60.0	33.3	4.0	2.7	0.0	14/7	4.20	90	75	0.89	61.0	26.3	8.0	4.0	0.7	8/8	4.50	86	82	0.91	66.7	22.7	8.0	2.3	0.3	3
4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	21/7	5.04	48	78	0.78	44.7	44.0	6.7	3.6	1.0	4
5	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	21/7	4.95	74	75	0.76	70.3	22.3	4.0	2.0	0.4	5
6	12/7	4.08	78	72	0.90	54.3	40.3	4.0	1.4	0.0	....	....	....	....	....	....	....	....	....	....	2/7	4.50	42	80	0.89	58.0	33.4	7.3	1.0	0.3	6
7	14/7	4.03	70	70	0.83	51.8	36.3	6.3	4.3	1.3	....	....	....	....	....	....	....	....	....	....	1/8	4.54	56	82	0.91	68.0	22.7	8.3	1.0	0.0	7
8	11/7	4.04	78	70	0.88	59.3	32.3	5.7	2.7	0.0	....	....	....	....	....	....	....	....	....	....	2/8	5.59	78	75	0.67	50.3	41.7	5.7	2.3	0.0	8
9	13/7	4.46	74	75	0.83	78.0	14.7	6.0	1.3	0.0	....	....	....	....	....	....	....	....	....	....	2/8	5.79	62	80	0.72	56.7	36.7	5.3	1.0	0.3	9
10	11/7	50.7	78	78	0.76	44.7	46.0	4.7	4.6	0.0	....	....	....	....	....	....	....	....	....	....	1/8	4.64	60	80	0.87	53.7	41.0	3.3	1.7	0.3	10
11	12/7	46.4	62	75	0.82	55.3	37.3	3.3	3.7	0.4	....	....	....	....	....	....	....	....	....	....	2/8	4.34	84	82	0.95	58.0	35.0	5.7	4.0	0.7	11
12	12/7	4.16	56	70	0.83	52.7	35.3	6.3	5.7	0.0	....	....	....	....	....	....	....	....	....	....	1/8	4.31	84	75	0.87	57.7	35.7	5.6	1.0	0.0	12
13	14/7	4.48	102	75	0.83	49.7	43.3	5.0	1.0	1.0	....	....	....	....	....	....	....	....	....	....	2/8	4.39	92	72	0.82	43.7	51.7	3.3	1.0	0.3	13
14	16/7	38.3	62	72	0.94	63.7	21.7	6.7	2.7	0.2	....	....	....	....	....	....	....	....	....	....	1/8	4.03	60	80	1.00	32.7	58.0	4.0	4.7	0.6	14
15	16/7	4.71	84	72	0.77	67.3	24.7	7.0	1.0	0.0	....	....	....	....	....	....	....	....	....	....	8/8	5.01	48	82	0.82	53.7	40.0	5.3	1.0	0.0	15
16	20/7	3.78	64	72	0.94	48.7	42.7	7.6	1.0	0.0	10/8	4.45	60	72	0.80	71.3	17.7	10.0	0.7	0.3	29/8	5.04	70	85	0.85	58.0	31.0	8.7	2.0	0.3	16
17	20/7	3.84	58	68	0.87	57.0	35.7	6.0	1.3	0.0	10/8	4.67	40	78	0.83	46.7	43.3	6.0	3.3	0.7	29/8	4.96	64	82	0.82	58.3	33.0	5.7	2.7	0.3	17
18	20/7	3.85	50	70	0.92	62.4	31.3	4.3	1.0	1.0	10/8	4.39	52	75	0.85	53.7	41.0	3.7	1.3	0.3	29/8	4.88	50	82	0.85	65.7	31.0	2.0	1.0	0.3	18
19	24/7	4.16	62	70	0.83	62.0	29.3	5.0	3.7	0.0	31/7	4.11	50	75	0.91	47.0	47.0	5.0	1.0	0.0	19/8	4.88	56	85	0.87	70.3	22.3	5.7	1.0	0.7	19
20	24/7	4.05	50	70	0.87	66.0	26.7	3.3	1.7	2.3	31/7	4.04	62	68	0.85	64.0	27.3	7.0	0.7	1.0	21/8	5.04	50	85	0.85	60.0	31.7	8.3	0.0	0.0	20
21	22/7	4.13	52	70	0.85	51.7	39.0	6.7	2.0	0.6	31/7	4.53	50	70	0.77	54.3	34.3	6.0	4.7	0.7	20/8	4.50	52	78	0.86	65.0	26.0	6.0	2.0	1.0	21
22	22/7	4.85	72	72	0.75	63.7	27.0	7.3	2.0	0.0	31/7	4.18	52	68	0.81	37.3	59.3	2.0	1.0	0.0	20/8	5.02	48	82	0.82	52.7	38.3	5.7	3.3	0.0	22
23	31/7	3.58	68	70	0.98	60.0	38.0	1.7	0.3	0.0	8/8	4.53	64	70	0.78	66.0	28.7	3.3	2.0	0.0	29/8	5.15	72	90	0.90	69.3	20.3	8.0	2.0	0.4	23
24	24/7	4.55	56	72	0.80	50.0	33.3	7.3	6.7	2.7	1/8	4.86	68	72	0.74	69.0	19.0	4.7	7.3	0.0	19/8	4.48	78	80	0.89	80.7	12.3	6.0	0.7	0.3	24
25	24/7	4.00	56	72	0.90	61.4	29.3	5.3	3.0	1.0	31/7	4.86	64	75	0.76	51.4	42.3	5.3	1.0	0.0	20/8	4.89	60	80	0.80	57.7	36.0	4.3	1.0	1.0	25
26	30/7	4.32	92	72	0.83	71.3	24.3	3.4	0.0	0.0	....	....	....	....	....	....	....	....	....	....	19/8	4.61	72	85	0.92	66.7	26.7	4.7	1.7	0.2	26
27	30/7	4.27	62	70	0.83	67.4	26.0	8.3	0.7	0.3	....	....	....	....	....	....	....	....	....	....	21/8	5.12	54	80	0.80	52.0	36.4	10.0	1.3	0.3	27
28	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	8/9	5.04	50	75	0.75	63.8	29.3	5.3	1.3	0.3	28
29	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	8/9	5.14	80	85	0.83	50.0	34.0	4.7	11.0	0.3	29
30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	8/9	4.85	72	82	0.84	59.3	32.0	5.3	2.7	0.7	30

*Cases 1 to 15 are from D.4: Cases 16 to 30, from D.3.

well over 4,000,000 and the majority well in the neighbourhood of, or over, 5,000,000.

White Blood Cells.—The white cell count showed little divergence from the normal (6,000 per c.mm.), but a glance at the admission counts and the last counts, show the latter to be generally higher than the former, and nearer the normal number. We may, therefore, say that the number of leucocytes in this disorder is unchanged or tends to a leucopenia.

The hemoglobin, as one would expect from the constant hemoglobinuria, was reduced in all cases, but not to the extent that the number of red cells on admission in the worst cases would indicate. It varied between 72 per cent. and 48 per cent. on admission; in only six cases was it 50 per cent. or less. The hemoglobin content improved more slowly than the number of red cells, as is usual in most anemias. At the time of the last estimation, roughly seven weeks after the last trip of the submarines, no blood contained less than 70 per cent. and the majority of bloods were up to 80 per cent. of the normal hemoglobin content.

The color index illustrates the relation of the hemoglobin to the red count. On admission it was generally high, twelve cases actually having an index over one. After a fortnight three cases were still over one. Before going on leave, no patient had an index over one, and only six had a color index above 0.9.

Differential Counts.—Three hundred leucocytes were counted in each case. There was nothing very characteristic about the differential counts; these varied greatly from week to week, both collectively and individually. A relative and an actual lymphocytosis (small mononuclears) was the general rule. This lymphocytosis was very marked in many cases. It seemed to reach its height about a week after admission, roughly a fortnight after the patient had left the submarine. For example, on admission only six men showed a small mononuclear count of over 50 per cent. (normal limits, 20 to 30 per cent.), whereas twelve reached 50 per cent. at the time of the second estimation. The greatest lymphocytosis was 71.3 per cent. (Case 1, 3d count). This is high enough to suggest leukemia in a case of unknown causation. The large mononuclear cells scarcely varied from the normal in any case, at any time.

The eosinophile leucocytes were increased above the normal in many cases at different times, suggesting that "eosinophile crises" are a feature of this toxemia. That the eosinophilia is not coincidental is shown by the numerous occasions on which it was above normal limits (4 per cent.), especially in the early counts; while in the last counts in only two cases (Nos. 1 and 29) did it exceed the normal. This shows that the increase of eosinophile cells did not occur when the blood had been restored to its original composition. In the two cases just mentioned, the blood of Case 1 was the slower in recovering. Case 29 had the highest eosinophilia throughout, with the blood otherwise little affected; therefore in his case the condition was probably an idiosyncrasy, or due to some undiscovered coincident cause.

All the chief points of the various blood counts are contained in Table 6. This table is made by averaging the weekly counts of six cases,—three (1, 2 and 6) from D.4, and three (16, 17 and 18), the earliest cases admitted from D.3. Figure 1 illustrates the same points graphically.

The following points previously discussed become evident at once in the dia-

TABLE 6

AVERAGE OF WEEKLY BLOOD FINDINGS OF SIX CASES OF ARSENIURETTED HYDROGEN POISONING

Time of Count	Millions of Reds per C. Mm.	No. of White Cells per C. Mm.	Hemoglobin per Cent.	Color Index	Lymphocytes per Cent.
On admission	2.34	5770	55.5	1.19	34.6
One week after	3.02	5330	60.8	1.04	47.2
Two weeks after	3.59	5100	67.1	0.94	51.5
Three weeks after	3.88	6170	70.0	0.90	39.4
Four weeks after	4.30	5520	72.4	0.85	33.5
Six weeks after	4.75	5700	81.5	0.86	33.3

gram (Fig. 1):

1. The steady rise in the number of red cells toward normal, quick at first, slowing down later.

2. The hemoglobin reduction which is not at first as low, in proportion, as the number of red cells. This line also rises steadily toward normal, but not as fast as the red cell line which crosses it at the middle of the second week.

3. The color index, at first above one, crossing to below the normal line at the same time exactly as the hemoglobin crosses the red cell line. (The index is, of course, above or below one, according as the number of red cells is less or more reduced in proportion to the hemoglobin content.) The index line drops more and more slowly till just at the time of the last count it is beginning to rise, showing that the hemoglobin is just beginning to catch up with the number of red cells.

4. The number of white cells is seen to be just a little below the normal line. This leukopenia is most marked at the second week.

5. The high percentage of lymphocytes is at its maximum at the second week, after which it slowly approaches the normal. It will be noted that the maximum relative lymphocytosis corresponds in time to the minimum number of white cells per cubic millimeter.

Theoretically, when the blood is perfectly recovered, all these lines should meet on the normal lines and coincide with them. They can all be seen to be approaching the normal lines at the time of the last count.

The Stained Films

In the majority of cases, the appearance of the red cells in stained films revealed very little change. At the time of admission there was some variation in size, many of the cells being smaller than, and a few larger than normal. A few of the earlier films exhibited a slight degree of general polychromasia. Nucleated red cells were present, but very scarce, in ten cases. Two notable exceptions to the above general description must be described, *viz.*, cases 17 and 18.

These two cases showed marked degenerative changes in the erythrocytes, microcytes and macrocytes being very numerous. Typical poikilocytosis was also present, a condition not noted in any of the other bloods. General basophilic staining and punctate basophilic stippling of the red cells was excessive. Erythroblasts were numerous, whereas, in all other cases, they were difficult to find and were always normoblasts if found. In these two cases both megaloblasts and normoblasts were easy to find, some of the cells exhibiting bi- or tripartite nuclei, while in many instances the non-nuclear part of the cell exhibited general basophilia and stippling. In Case 17 the number of nucleated reds per 300

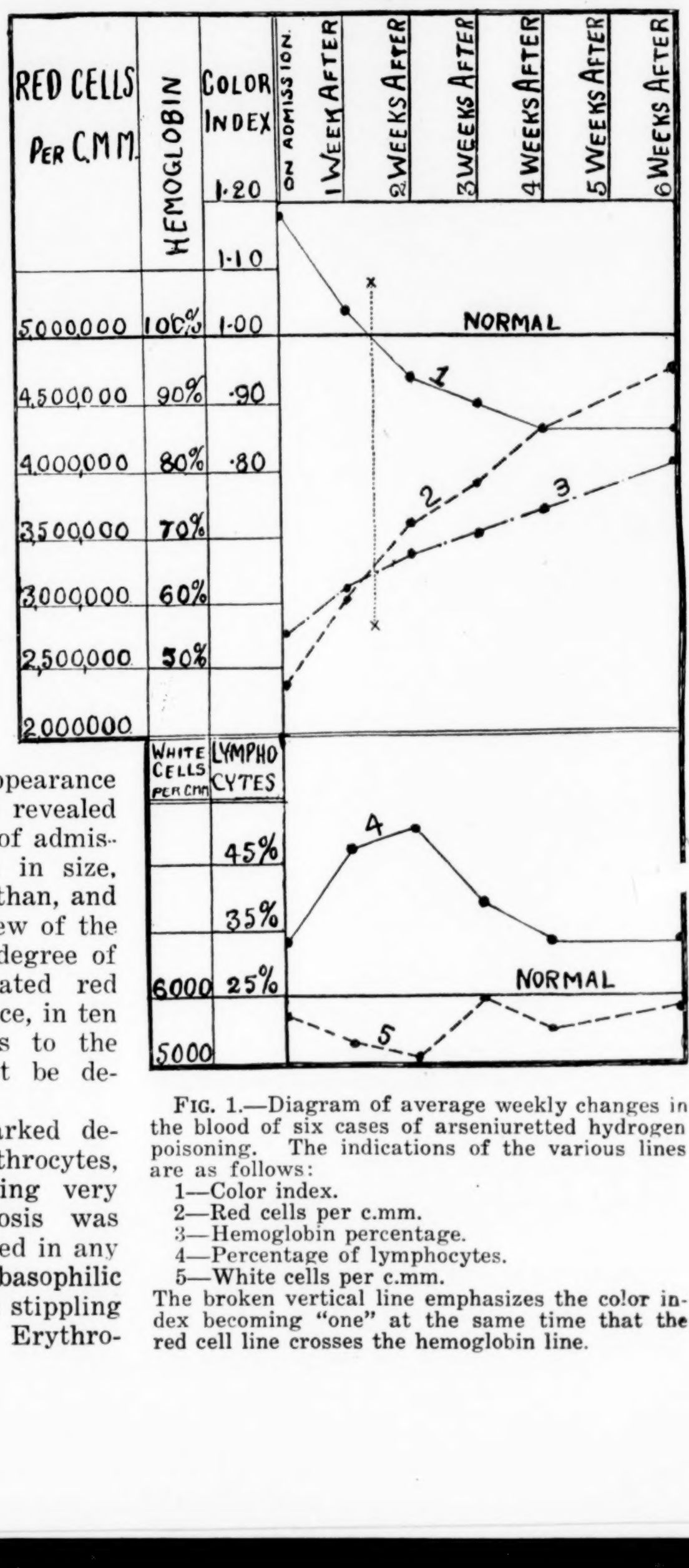

FIG. 1.—Diagram of average weekly changes in the blood of six cases of arseniuretted hydrogen poisoning. The indications of the various lines are as follows:

1—Color index.
2—Red cells per c.mm.
3—Hemoglobin percentage.
4—Percentage of lymphocytes.
5—White cells per c.mm.

The broken vertical line emphasizes the color index becoming "one" at the same time that the red cell line crosses the hemoglobin line.

white cells was two megaloblasts and three normoblasts. Case 18 showed the worst blood seen. In a differential count of three hundred white cells, fourteen megaloblasts and eight normoblasts were counted.

Let us review for a moment the blood findings in this case as shown in Table 4. What is found? A man with less than 2,000,000 red cells, a high color index, advanced degenerative changes in the reds, numerous erythroblasts, megaloblasts more plentiful than normoblasts, and bile-stained serum. What is this blood? Obviously a case of pernicious anemia. Could it be any other condition? Extremely unlikely, yet it is. Does it throw any light on the etiology of pernicious anemia? To my mind, it is extremely suggestive of a toxemic cause for the latter. In my opinion the most extraordinary observation made in this condition was the rate at which the advanced degenerative blood picture disappeared. Three days later, that is, five days after being removed from the influence of the poisonous gas, these two bloods were re-examined. Polychromasia and variation in the size of the red cells were no more marked than in many of the other bloods. Poikilocytes and stippled cells were remarkable for their absence. Two nucleated red cells (normoblasts), were discovered in the film from Case 18 and not one in Case 17, while 300 white cells were counted. The above facts were so startling that I sent the slides to Dr. Bassett-Smith who confirmed my findings. These two patients (with Case 16), were seen within forty-eight hours of leaving their boat, whereas no other men arrived at Chatham till five days had elapsed. This rapid clearing up of the changes in the red cells leads one to think that many other cases would have presented the same changes if seen earlier. However, against this view, is the fact that Case 16 did not present these changes though admitted at the same time as Cases 17 and 18. In Case 16 nucleated reds were very scarce, and there was slight polychromasia and variations in the size of the red cells, but nothing approaching the changes in 17 and 18.

The Fragility of the Red Cells

Some other observations were made on the blood of these cases. It was thought that the action of the gas might have damaged the walls of the blood corpuscles causing them to be more "fragile," that is more permeable to the escape of their contents than normal blood corpuscles. The fragility of a red cell is indicated by the amount of salt that must be added to distilled water to prevent the escape of its hemoglobin. In normal blood only 0.3 to 0.4 per cent. of salt is necessary to prevent laking. Increase in fragility is an especial feature in acholuric jaundice which seems in some ways analogous to this toxemia. An increase of fragility was expected. Contrary to expectation, it was found that the cells of these submarine cases were, if anything, less fragile than usual at the time they were examined. Four cases, Nos. 4, 6, 17 and 18, were tested the day of admission and after their return from leave. My own blood, which has been tested many times with invariably the same results, was used as a control to each test. Table 7 shows the results of the tests.

The point at which some of the cells begin to lose their hemoglobin is indicated by the strongest percentage of salt solution to show any coloration of the supernatant fluid when the cells settle to the bottom of the tube containing the mixture. The point of complete loss of hemoglobin by all the cells is shown by the strongest salt solution in which no cells settle to the bottom of the tube (complete hemolysis). A glance at Table 7 shows that there was little change in the fragility. In fact, the tendency was for fragility to be less marked in the patients' bloods than in the control, and, what is more striking, the bloods were more fragile if anything when the patients had recovered than on their admission (except Case 6). If this is a fact, the strength of the cells to resist osmotic pressure is increased in cases recovering from arseniuretted hydrogen poisoning. I would venture the following possible explanations: Either the gas destroyed all the weaker cells so that those left at the time of admission were stronger than normal, or, more likely, in these cases the average size of the red cells tended to be a little smaller than normal (see above). Mathematically, provided other factors were equal, it would take a greater osmotic pressure to stretch the wall of a

small sphere or corpuscle to the same extent as a large one. Thus a blood with small corpuscles would be less fragile than one with large corpuscles, presuming all other factors to be equal. [N.B. It is a well known hydrostatic formula that $2T = PR$, where T= the tension on the wall of a sphere: P=Pressure in the sphere (in this case osmotic pressure): R=Radius of the sphere. If P remains constant, T varies directly as R.]

The serum of these four cases was deeply bile stained and gave the usual bile reactions. No free hemoglobin or methemoglobin could be detected by the spectroscope in the serum after removal of the blood corpuscles by centrifuging.

TABLE 7
RED CELL FRAGILITY TESTS*

	On Date of Admission			On Return from Leave		
No. of Case	Complete Hemolysis	Partial Hemolysis	No Hemolysis	Complete	Partial	No
Control	0.4	0.425	0.45	0.4	0.425	0.45
4	0.375	0.4, 0.425	0.45	0.4	0.425	0.45
6	0.425	0.45	0.475	0.4	0.425, 0.45	0.475
17	0.325	0.35, 0.375, 0.4	0.425	0.375	0.4	0.45
18	0.35	0.375, 0.4	0.425	0.375	0.4	0.45

*The figures given are percentages of sodium chloride solution.

The Arneth Count

This method is not yet in common use, but I am sure it is one which deserves more attention. Briefly, the way in which the count is performed is this. One hundred polymorphonuclear leucocytes are counted and are divided into five classes, according as the nucleus of the cell has 1, 2, 3, 4, or 5 divisions. It has been found that the proportion of cells in each class remains fairly constant in health, but in any toxic condition the cells with fewer divisions in their nuclei increase, and classes 1 and 2 exceed classes 3, 4 and 5. So considerable is this "drift to the left," that to my mind it disposes of the great disadvantage of the count, i.e., the personal element. There is no doubt personal equation comes in very strongly in these counts since the divisions between the five classes are not always sharp, but if each investigator practices by counting normal bloods he will get his own idea of a normal count as compared with other investigators. It should be insisted too, that cells must only be counted in thin parts of the film where the red blood corpuscles are spread out to a single layer and the leucocytes well flattened. If these two points were consistently regarded results would become more comparative.

Ten bloods from naval ratings in apparently perfect health gave the following average counts:

Case	Cell Class					Per Cent. Classes 1 and 2	Per Cent. Classes 3, 4 and 5
	1	2	3	4	5		
Average count of ten normal bloods	16.6	25.8	42.9	12.7	2.0	42.4	57.6
A. Blood of healthy man, with largest number of cells in Classes 1 and 2.	20	31	37	10	2	51	49
B. Blood of healthy man, with smallest number of cells in Classes 1 and 2	10	21	44	21	4	31	69

My average count gives classes 1 and 2 a little higher than Arneth's normal which is 40 per cent. Counts *A* and *B* give the widest variations among the ten healthy men examined. A count like *A* does suggest some mild undiscovered toxemia, such as a bad tooth.

Allowing a big margin for error, one may safely say that if the cells in classes 1 and 2 exceed in number those in 3, 4, and 5, the case in question is suffering from a toxic condition of some sort. Table 8 contains the Arneth counts on eleven of these submarine cases. Each case had three counts done from blood films taken on admission, about three weeks later, and on returning from leave. In addition an average count was made from the eleven counts in each period.

An inspection of the average count shows that on admission the cells in

classes 1 and 2 reached over 80 per cent., double the normal number to be expected in health. After three weeks, the average count had dropped to 69.2 per cent.; on return from leave it was 56.9 per cent. This last fact indicates that the blood was still reacting to some toxic agent, though there were no symptoms in any case and scarcely any indications in the ordinary blood examinations to suggest that the men, on their return from leave, were in any way toxemic.

Turning to the individual counts, it will be seen that most cases showed progressive improvement, Cases 6, 23, 25 and 26 being practically "normal" at the time the blood for their last count was taken. Case 4 is peculiar; his Arneth count showed little reaction on admission but remained the same on the two subsequent occasions. Cases 5 and 21 showed marked reactions in the first counts, reactions which did not improve to any appreciable extent in the other two counts. If this method of examination is reliable it may be another indication of the well-known fact that the elimination of arsenic is much slower in some people than in others. For example, Case 21, seven weeks after exposure to arseniuretted hydrogen, still retained sufficient arsenic to give a marked toxic Arneth count in his blood, whereas in the same period Case 23 had eliminated all of his arsenic and had a normal count.

TABLE 8

ARNETH COUNTS ON ELEVEN CASES OF ARSENIURETTED HYDROGEN POISONING

Case	On Admission							Three Weeks Later							On Returning from Leave						
	Cell Class					Per Cent. Classes 1 and 2	Per Cent. Classes 3, 4 and 5	Cell Class					Per Cent. Classes 1 and 2	Per Cent. Classes 3, 4 and 5	Cell Class					Per Cent. Classes 1 and 2	Per Cent. Classes 3, 4 and 5
	1	2	3	4	5			1	2	3	4	5			1	2	3	4	5		
1	36	40	21	3	0	76	24	25	46	26	2	1	71	29	30	34	32	4	0	64	36
4	21	37	32	10	0	58	42	20	31	43	6	0	51	49	25	33	34	7	1	58	42
5	48	35	15	2	0	83	17	30	40	27	3	0	70	30	43	32	20	5	0	75	25
6	50	40	10	0	0	90	10	24	37	28	9	2	61	39	15	33	40	10	2	48	52
16	48	38	13	1	0	86	14	41	35	19	5	0	76	24	24	33	34	9	0	57	43
17	42	42	14	2	0	84	16	35	40	22	3	0	75	25	25	44	27	4	0	69	31
18	64	28	7	1	0	92	8	38	48	10	4	0	86	14	18	31	41	9	1	49	51
21	59	27	11	3	0	86	14	45	38	15	2	0	83	17	44	39	15	2	0	83	17
23	36	44	18	2	0	80	20	18	35	34	13	0	53	47	11	29	52	8	0	40	60
25	35	44	19	2	0	79	21	26	42	27	5	0	68	32	16	25	48	10	1	41	59
26	45	36	19	0	0	81	19	26	41	26	7	0	67	33	15	27	44	14	0	42	58
Average Count	44	37.3	16.3	2.4	0	81.3	18.7	29.8	39.4	25.1	5.4	0.3	69.2	30.8	24.2	32.7	35.2	7.4	0.5	56.9	43.1

THE BLOOD PRESSURE

In some conditions, such as blackwater fever, where the destruction of blood cells and hemoglobinuria are marked symptoms, the blood pressure is considerably lowered. Unfortunately, I did not know this fact till Fleet Surgeon Bassett-Smith told me of it, so the cases had been in the hospital some time before I tried to find out if the blood pressure was lowered in this toxemia. Table 9 gives a list of systolic blood pressures in millimeters of mercury, with the dates on which the observations were taken. The first column contains pressures taken before the patients went on leave, and the second column pressures taken after return from leave. This table shows nothing of much interest. Case 6 had an abnormally high pressure which was checked on two occasions; no cause could be found for it. There is no very marked difference in the pressure before and after leave. The four cases with systolic pressures below 120 mm. before going on leave, included the two cases in which the bloods showed the most marked changes (Cases 17 and 18), and the pressure in these two cases had gone up considerably by the time they were readmitted to the hospital. This is the only indication that the blood pressure may have been considerably reduced in the acute stages of the toxemia. It should be noted that the blood pressure in

nearly all these men is higher than is generally to be expected in men of their age. In this connection my experience seems to be the same as that of Surgeon Lovel Moss, who suggests that the average sailor has a higher blood pressure for his age than is usual (*Journal of The Royal Naval Medical Service*, October, 1916), or perhaps the higher average pressure is due to a residual effect of the poison on the kidneys or vessels.

ARSENIC EXAMINATIONS

The following tests for arsenic were done:—

1. *Urine.*—Forty to sixty ounces of the urine passed during two days after admission were concentrated and examined for arsenic in eighteen cases. Only three cases gave positive results:

Case 16.....A trace
Cases 17 and 18.....Very strong mirrors of arsenic.
} Urine examined within 3 days of leaving submarine.

These three cases were the only ones whose urine was tested less than a week after leaving the submarine.

2. *Blood.*—Twenty-five cubic centimeters of blood were drawn off the day of admission from Cases 17 and 18. No arsenic could be recovered from this amount of blood and serum.

3. *Finger and Toe Nails.*—Finger and toe nails examined gave no individual positive results, but the nail parings of ten cases mixed together and tested by Reinsch's test proved the presence of arsenic in the finger and toe nails.

4. *Hair.*—My own earlier examinations by Reinsch's test were negative but I was using too coarse a technique and too small quantities of hair. Early samples from twelve cases of both hair and nail parings were sent to Greenwich where Dr. Bassett-Smith and Professor Brain obtained positive results in seven out of twelve cases; they also confirmed the presence of arsenic in the urine of Case 18. Using more delicate apparatus and technique (recommended in the *Report of The Royal Commission on Arsenic Poisoning*) and 2 gm. of hair in each case, I examined seven men's hair a month to six weeks after they had left the submarine. The results are tabulated as follows: those which gave the strongest positive results being placed first:

TABLE 9

SYSTOLIC BLOOD PRESSURE IN CASES OF ARSENIURETTED HYDROGEN POISONING

No. of Case	Date of Admission (1916)	Date of Observation (1916)	Blood Pressure 1: Before Going on Leave	Date of Observation (1916)	Blood Pressure 2: After Return from Leave
1	15/6	.....	.....	1/8	135
2	15/6	.....	.....	1/8	143
6	20/6	.....	.....	1/8	170
7	20/6	.....	.....	1/8	124
8	20/6	.....	.....	2/8	130
9	20/6	.....	.....	2/8	132
10	21/6	.....	.....	1/8	140
11	21/6	.....	.....	2/8	134
12	21/6	.....	.....	1/8	145
13	21/6	.....	.....	2/8	134
14	24/6	.....	.....	1/8	138
15	24/6	.....	.....	3/8	134
16	29/6	21/7	142	29/8	128
17	29/6	25/7	118	29/8	138
18	29/6	25/7	108	29/8	125
19	1/7	25/7	140	21/8	132
20	1/7	25/7	136	21/8	140
21	1/7	25/7	124	21/8	128
22	1/7	25/7	114	21/8	125
23	1/7	25/7	110	30/8	132
24	1/7	25/7	129	21/8	130
25	1/7	24/7	135	21/8	135
26	7/7	27/7	135	21/8	132
27	7/7	25/7	126	21/8	152
28	28/7	3/8	130	11/9	120
29	28/7	3/8	130	11/9	125
30	28/7	3/8	125	11/9	130

Case Reference No.	Result of Marshing
17	Dense brown-black deposit of arsenic
16	Very good mirror
18	Very good mirror
23	Good mirror
28	Large trace
29	Small trace
30	Small trace

Though I have far too little experience to do quantitative arsenic estimations, it is interesting to note that the largest amount of arsenic was obtained from the hair of the man with the most persistent albuminuria; that the smallest amounts were from two cases who had been in three trips each but had had very mild symptoms only. It certainly looks as if these latter did not absorb the arsenic inhaled to the same extent as the former, or else excreted it at once by the urine and feces. Though a skilled chemist would probably have obtained more positive results, I think arsenic has been recovered often enough to prove it definitely to be the cause of the condition. Numerous blank experiments were performed with the apparatus and reagents to make certain they were arsenic free, so the positive results that were obtained can be relied on.

THE ACTION OF ARSENIURETTED HYDROGEN ON BLOOD

To perform these experiments, arseniuretted hydrogen was generated by adding at short intervals small quantities of a 1 per cent. solution of arsenic trioxide in dilute hydrochloric acid to a hydrogen apparatus. The delivery tube of this apparatus dipped into a small flask containing the fluid under observation, so that the mixture of hydrogen and arseniuretted hydrogen evolved could be bubbled through it. Hydrogen has no action on the blood, so any results obtained were due to arseniuretted hydrogen. For precaution's sake these experiments were performed in the open air. If arseniuretted hydrogen produced in this way is passed through blood to which enough sodium citrate solution has been added to prevent clotting, the blood gradually darkens to a chocolate color. No further darkening can be detected after the gas has been passing from four to eight minutes. Exactly the same thing happens if, instead of using the whole blood, blood cells which have been washed four times in physiological saline solution are used.

Samples of blood and washed blood cells were treated with the gas for fifteen and forty-five minutes, and were then examined with the microscope and spectroscope. The observed changes were similar in all respects whether the whole blood or only washed blood cells were used, or whether the time of exposure to the gas was short or long. The samples all darkened to a dark chocolate color. On centrifuging, a perfectly colorless supernatant fluid was obtained, no trace of hemolysis having occurred. The deposits of "red" cells at the bottom of the centrifuge tubes were almost black. Stained films made from the centrifuged cells appeared absolutely normal; no changes could be detected in the red or white corpuscles. Wet unstained preparations also revealed no discernible change. There were no broken or swollen cells, nor were there any cell "ghosts" (i.e., red cells which have lost their colored contents). No agglutination or clumping of the red cells could be seen in these wet preparations. On standing overnight the supernatant fluid was tinged brown, but only a little more than controls of untreated blood were tinged red. Some of the dark colored cells were laked to a chocolate colored solution by the addition of distilled water, and examined with a spectroscope. (N.B.—The only spectroscope at my disposal was a small direct vision instrument, so very detailed or accurate spectrum analysis was not to be expected.) The spectrum of oxyhemoglobin was very evident, the two characteristic absorption bands between the *D* and *E* lines seemed to be as strong as in normal blood. In some samples, suitably diluted, the absorption band of methemoglobin in the red part of the spectrum between the *C* and *D* lines could be faintly made out, but only with great difficulty. The oxyhemoglobin gave the usual reactions; a drop of ammonium sulphide solution gave the spectrum of reduced hemoglobin, and a drop of potassium ferricyanide solution at once produced a *strong* methemoglobin spectrum, with *no further darkening* of the solution.

Another experiment was performed on blood which had been laked by distilled water before the arseniuretted hydrogen

was passed through it. On passing the gas through this hemolysed blood, instead of taking four to eight minutes, the solution almost immediately became a deep chocolate brown. A spectroscopic examination of this fluid revealed a strong methemoglobin spectrum with no sign of the oxyhemoglobin spectrum. This spectrum gave the ordinary changes to be expected on treating the fluid with ammonium sulphide or acids.

To see if arseniuretted hydrogen had any tendency at all to cause hemolysis, this experiment was devised. Blood was well diluted with 0.5 per cent. sodium chloride solution instead of 0.9 per cent., with the idea of increasing the permeability of the red cells by using a hypotonic salt solution. Still no trace of hemolysis occurred after passing the gas for an hour, but on standing for four or five hours some of the corpuscles had discharged their contents, as revealed by the color of the salt solution and by the microscope.

These experiments show that arseniuretted hydrogen has little obvious effect on blood *in vitro* except to change its color. On laked cells, however, that is on a solution of oxyhemoglobin, it has the power of quickly converting the whole of it into methemoglobin; whereas if the oxyhemoglobin is in the red cells instead of free in solution, the arseniuretted hydrogen has much more difficulty in effecting this change and seems only able to convert a small part of the coloring matter in the cells into methemoglobin. The marked change in the color of the blood would indicate that most of the coloring matter had become methemoglobin, but, as seen above, the spectroscope does not confirm this view.

I thought at first that arseniuretted hydrogen might form a compound with hemoglobin analogous to carboxyhemoglobin, but the spectrum obtained after passage of arseniuretted hydrogen through blood is, as far as I can make out, identical with oxyhemoglobin, and gives all the reactions of the latter. But the marked change in color, combined with the difficulty of obtaining the methemoglobin spectrum in whole blood, does suggest that arseniuretted hydrogen enters into a loose preliminary combination with the cells, which is indicated by a darkening of the color. The experiments also show that the gas has very little or no tendency to cause hemolysis, though the last experiment does suggest that it damages or increases the permeability of the cell membranes very slightly if helped by the action of a hypotonic solution of salt.

The absence of the fluid components of the blood makes no difference to the above phenomena, so complement or other constituents of the blood plasma are not necessary in these reactions.

Though caution is necessary in making deductions as to what happens *in vivo* from experiments *in vitro*, it seems as if arseniuretted hydrogen does not itself directly cause the liberation of blood pigments into the serum but damages or alters the contents of the red cells. Probably the liver, one of the functions of which is to remove useless blood cells, destroys these altered cells and liberates the pigment. Provided too many damaged cells are not thrown into the liver, the pigment is converted into bile. This bile, owing to congestion of the bile ducts or to some other reason, arrives in the general circulation by the hepatic veins, giving rise to the jaundice and to bile in the urine. From the men's descriptions of the color of their urine as being brown rather than reddish, in many cases, and from Fleet Surgeon O'Malley's account of cases not sent to the hospital, it would seem that in many cases bile only, and no blood pigments, appeared in the urine. If, however, a large excess of damaged cells were produced, probably so great a strain was thrown on the liver that it could not convert all the blood pigments into bile, and consequently hemoglobin and methemoglobin appeared in the urine in the more acute cases. (Incidentally some of the blood pigments and any whole blood that appeared in the urine might have been due to the accompanying toxic nephritis.)

The above hypothesis fits the facts and appears more reasonable than the theory that the blood cells were directly hemolysed in the blood vessels by the gas absorbed into the circulation. It also places the origin of the jaundice in the liver, where in all other cases it has been proved to arise, and does away with any necessity of considering this condition to be a hematogenous jaundice.

MEN NOT ADMITTED TO HOSPITAL

The preceding pages deal only with cases that were admitted to the Royal Naval Hospital, Chatham, and came personally under my own observation. I have obtained a few facts about the other members of the boats' crews from Fleet Surgeon O'Malley and from the commander of D.3.

There were fifty-six men in the crews of both boats; of these, thirty were considered bad enough to be sent to the hospital; fifteen were on the sick list of their parent ship with mild symptoms; two men were sent to Shotley Sick Quarters with an "erythematous rubelliform rash." These two, with Case 16, are the only three who had skin lesions, and these not especially typical of arsenical poisoning. The rashes were probably manifestations of a toxemia, analogous to the erythemas which sometimes follow the intravenous injection of salvarsan and other arsenical compounds. The remaining eleven men, though nearly all of them felt seedy and had symptoms during the trips, felt quite fit to carry on their duty on return. There was, however, one E.R.A. in D.3, who went through all three trips and maintained he felt no symptoms or effects whatever. Thus, we have, out of 56 men exposed to the gas, 30 men bad enough to be sent to the hospital; 15 men bad enough to be put on the sick list for a day or two; 10 with symptoms so mild that they could carry on duty; and 1 with no symptoms whatever. This list excludes the new hands in D.3's third voyage.

CONCLUSION

A feature of this outbreak of poisoning is the remarkable difference in the way individuals reacted to the gas. There is a complete graduation of symptoms, from a man who was apparently unaffected at all to a patient with such marked signs and symptoms as Case 18. This variation in effect was seen to be just as well marked in the blood changes as in the subjective signs. Now all the men in the same boat must have had equal chances of getting the same dose of the poison. The air in a submerged submarine must be well mixed, since the amount of carbon dioxide is so great that unless the air is kept circulating respiration becomes uncomfortable. (A note on one of the case sheets states there was 2.99 per cent. of carbon dioxide in D.4's atmosphere.) The result of this circulation would have been to distribute equally throughout the boat any arseniuretted hydrogen in the air. It was also found on inquiry that the fact of a man's station being forward or aft near the batteries, had no relation to the severity of his illness; for example, the two captains had sleeping bunks just above the battery boards and neither felt bad enough to go sick on return to harbor. This all points to individual idiosyncrasy as the cause of mild or severe symptoms since all the men probably inhaled an equal volume of the gas. In some cases the greater part of the inspired gas may have been absorbed by the lung epithelium, while in others most of the gas may simply have been exhaled again, or considering the minute quantity that must have been present and the well-known difference in the rate of excretion of arsenic in different people, the men with mild symptoms may have got rid of the gas as quickly as they absorbed it, while severer cases fixed a considerable proportion in their systems. The estimations of arsenic in the hair support this view.

Two rather peculiar statements deserve mention. One or two ratings said they felt worse when they lay down in the boat. Arseniuretted hydrogen is heavier than air but in spite of this, for reasons stated, I do not think the air at the bottom of the boat could have contained more of it than the air higher up. Nearly all the men stated that their symptoms, especially nausea and dyspnea, were worse just after breaking surface and getting into the fresh air. I thought at first that this might be due to the decrease of atmospheric pressure lowering the oxygen capacity of an already anemic blood. But there is practically no excess of pressure in a submerged submarine, and it is probably analogous to a well-known fact in alcohol toxemia, *viz.*, a man, who may have shown no symptoms of drunkenness in a hot ill-ventilated room, will suddenly develop symptoms on coming out into the cold fresh air.

This series of cases differs in one or two points from any previously described cases of arseniuretted hydrogen poisoning that I could find. The best description

and summary of arseniuretted hydrogen poisoning that I have seen is one by Dixon Mann* (*Medical Chronicle*, 1895). He describes five cases and summarizes forty-six in all. They were all acute, due to a sudden big dose of the gas, generally in some trade process in which impure acid was used to dissolve zinc. The symptoms upon which special stress is laid and which occurred most generally, were vomiting with pain in the epigastrum, hemoglobinuria, jaundice and rigors. Though albumin and fatty casts were common, the urine became normal very quickly in those cases that recovered. In the few cases in which the blood was examined, the red blood corpuscles were reduced. The mortality was 36.7 per cent.

It is interesting to note how these submarine cases differ from those of the literature. The main symptoms are the same except that not one of my cases had rigors. Persistent albuminuria and mild neuritic symptoms, though fairly constant in this series, are not even mentioned in Dixon Mann's paper. The onset was delayed two or three days or even longer in some of these cases, whereas in the previously reported cases the onset was generally immediate, or at any rate occurred within ten hours. The dose of poison, though small, continued to be administered after symptoms started. There was no morfality. These submarine cases are therefore unique. Under ordinary circumstances there are probably no other conditions, except during service in a submarine, under which men could be exposed to the action of a virulent poison, giving rise to very unpleasant symptoms, and have to remain in contact with it. In any trade process, should the gas be evolved in a closed room, the workers would at once, at the onset of symptoms, remove themselves from vicinity of the gas and would not remain in contact with it for seven or eight days as these men had to do. These cases are therefore the only reported instances of a chronic or subacute poisoning with arseniuretted hydrogen. The main difference from the acute form of poisoning is that there is time to accumulate sufficient arsenic to superimpose the peripheral neuritis symptoms of chronic arsenic poisoning on the symptoms caused by the direct action of the gas on the blood. The cases occurring in D.3's third voyage correspond to the ordinary acute form, of which Case 28 is an example. This patient's symptoms were marked but he made a rapid recovery with no neuritic symptoms or albumin in his urine after the third day. If this third trip of D.3 had been continued it is quite likely that more severe, if not fatal, cases would have occurred, since the symptoms started earlier, were more general, and were temporarily more severe than those of the previous trips. These cases all recovered merely with rest, blood tonics, and fresh air; there seemed to be no indications for special treatment, though direct transfusion of whole blood is a point worth considering in a severe case.

In conclusion, one cannot help feeling there is cause to be thankful that no catastrophe occurred, and that no life was lost before the nature of this malady in the submarines was discovered. The previously reported mortality from this form of poisoning is 36.7 per cent., so one can imagine its effect if present in any quantity, instead of in mere traces, in a closed space like a submarine from which there is no escape. It is possible even to conceive of a submarine never returning, her loss put down to the act of the enemy or hazard of the sea, whereas in reality her whole crew perished from the effects of this deadly poison.

ADDENDUM

Inquiry was made by the firm which had installed the batteries in the submarines as to the possible origin of the arseniuretted hydrogen gas, and the following is the substance of their report.

The battery on Submarine D.3 was first charged in November, 1910, and that on D.4 in 1911. As the batteries had been in use continuously for over five years and no previous trouble had been experienced, it was naturally thought that some arsenic-contaminated sulphuric acid had been recently added to the cells. Samples of electrolyte taken from the batteries and subjected to Marsh's test did not show an arsenic reaction. A sample of strong acid was then taken from a carboy, stated

*At the time of writing I had not seen Professor Glaister's book on Arseniuretted Hydrogen Poisoning.

to be one of the batch from which the acid was obtained for topping up the cells when the poisoning had occurred. On applying Marsh's test only a slight arsenic reaction was obtained. Endeavors were made to detect arseniuretted hydrogen gas in the gases given off when the battery was charging, but these were unsuccessful. Removal of the battery from the boat in order to facilitate chemical investigation was decided on.

Meanwhile laboratory tests, introducing arsenic impurity in various amounts into the electrolyte, gave only slight traces of the evolution of arseniuretted hydrogen gas. It was observed, however, that the arsenic introduced into the electrolyte in considerable quantities, was for the most part deposited as a chocolate brown precipitate on the elements, separators, and container sides, which precipitate resisted the action of charge and discharge.

On testing the battery from D.3 from which the acid had been changed, it was found that the gases evolved on charging from nearly all the cells, produced an arsenic coloration on mercuric chloride paper. The next step was to examine the active materials and grids of the plates. The active material from both plates gave no indication of arsenical deposit, which disposed of the original suspicion that arsenical contamination of the topping up acid was the cause of the trouble, because from the experiments cited arsenical contamination in the electrolyte would have produced arsenical deposit on the plates.

The examination of the metallic portion of the plates showed 0.2 per cent. of arsenic, and proved this to be the source of the poisoning. At the time the grids were made, antimonial lead alloy was used. The original surface of the grid had been deeply corroded, the effect of which was to convert slowly the metallic lead in the alloy into insoluble lead peroxide, and enable arsenic to pass into solution. The rate at which the arsenic would pass into solution would be negligible until the gassing period of the charge was reached, at which point the corrosive impurities in the electrolyte, assisted by electro-chemical action, would dissolve the arsenic exposed by the corrosive action on the alloy. The arsenic dissolved in the electrolyte would be carried to the negative electrode in small quantities as dissolved, and there converted into arseniuretted hydrogen gas by the nascent hydrogen at this electrode.

The presence of an excessive amount of corrosive impurity can be easily accounted for by the fact that the electrolyte had not been changed since the battery was installed in 1911, hence the accumulation of oxyacids of chlorine, arising from the sea air, carried over during the ventilation. This explanation accounts for the fact that only very minute traces of arsenic could be detected in the electrolyte. It may be noted that under war conditions, it is not always possible to ventilate the batteries into the atmosphere for a short period after charging has ceased. Could this always be done it would, in all probability, prevent any arseniuretted hydrogen getting into the interior of the boat, as gas is only evolved during charge, and only occluded gases come off for a short period after charging is stopped.

In the later batteries, as in those of the submarine class E, the grid castings were made of an alloy made from lead and pure antimony, instead of the antimonial lead alloy. In recent years antimony of high purity has been obtainable commercially. It was therefore not expected that any repetition of the trouble would be experienced, and actual tests made on the gases from many of the E class batteries do not show the presence of any arseniuretted hydrogen gas.

When the source of arsenic was discovered, all the batteries on the submarines of classes C and D were removed.

A PRACTICAL STUDY IN INDUSTRIAL FATIGUE *

HENRY C. LINK, Ph.D.

ORIGIN

THIS study was undertaken at the request of a large manufacturing concern in order to determine certain facts regarding the effects of fatigue on the work of shell inspection. A quotation from the letter which initiated the study will indicate the practical problem: "One of our most serious troubles recently has been defects in cartridges which might have been caught by the shell inspectors had their work been of a better quality." It was of the utmost importance at the time this study was undertaken to combine a maximum quantity of production with a maximum of quality. Therefore, the hours and conditions under which the work of inspection was being done were matters of great solicitude. The ten-hour day was in vogue, with a half holiday Saturdays.

For the sake of clarity it is necessary to explain briefly the work in question. All cartridge shells, before being loaded, must be given a very careful visual inspection. This work was being done by about 150 girls, in a large, well-lighted shop, under uniform conditions. Each girl sat before a hollow table, upon which was dumped a large box of brass shells. The inspector would pick these shells up, using both hands, and inspect them for a variety of defects. The defects to be looked for were often very small. Defective shells were thrown into small boxes, and the good shells were dropped through a chute into a large box below. It is apparent that the work was very light from the standpoint of the muscular energy expended, but quite strenuous in the steady and continuous attention which it required. The work was done on a piece-work basis, with an extra 10 per cent. and 20 per cent. bonus for doing more than a certain number of pounds of work (shells) per day. Each box of shells, after it had been inspected, was reinspected by a check-inspector, who sampled a certain number of the shells in the box. If this reinspection showed a certain number of defective shells still present, the entire box was sent back to the girl responsible, and she had to inspect the box again, this time without pay.

METHODS OF APPROACH

This study was conducted from four different angles:

(1) By means of a reinspection,
(2) By means of psychological tests,
(3) By means of a careful production study,
(4) By means of ordinary observation.

REINSPECTION

An impression existed that the quality of the work done during the latter part of the day was greatly inferior to the quality of the work done during the earlier hours, so inferior, in fact, that it did not pay to work during the last hour or two, between 4 and 6 o'clock. Another large company, acting on this assumption, had taken some of the shells inspected by their girls after 5 o'clock and unknown to the girls themselves had returned them for reinspection the following morning. A surprising amount of "scrap" (defective shells) was found. On the strength of this test, the hours for inspection at this plant were reduced from ten to eight and one-half. A similar experiment had been tried here and a considerable amount of scrap had been found. Consequently, there was a tendency to take the same step here in reducing the length of the working day. Obviously, there was no justification for such a decision, for the tests made proved nothing whatsoever about the comparative quality of the work done at *different* times of the day.

The method used in this study was as follows: A number of boxes of shells which had been inspected the first thing in the morning were separated and returned, surreptitiously, to the same girls for reinspection later in the day. This was also done with boxes inspected by the same

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*The conduct of this study was shared equally by Mr. John L. Koehne, A. B., Miss Marion Gilbert, A. B., and the writer. Received for publication June 2, 1919.

girls between 5 and 6 P. M. and between 1 and 2.30. In every case, the scrap thrown out at the reinspection was saved and analyzed. Only ten boxes were handled at a time, to avoid interfering with production, and also in order to make a wide distribution of the samples. The reinspection was done at different times of the day, in order to distribute the possible sources of error. The scrap found in all of these boxes was totalled and averaged with the following results:

	Time of Original Inspection		
	7-8 A.M.	1-2.30 P.M.	5-6 P.M.
Number of Boxes Inspected	47.0	26.0	37.0
Percentage of Total Scrap Found by Reinspection	12.2	8.5	15.5
Percentage of Scrap (Based on Total Number of Shells Inspected) Found by Reinspection	3.9	2.6	5 3

From the above it will be seen that 3.3 per cent. more scrap was overlooked between 5 and 6 in the afternoon than was overlooked between 7 and 8 in the morning, and 7 per cent. more than between 1 and 2.30. These variations are not quite so great when figured on the basis of the total number of shells in an average box. Computed in this way, the percentage of scrap overlooked at night is 1.4 per cent. of the total number of shells more than in the morning. This increase was comparatively slight and could have been easily overcome by requiring the check-inspectors to sample the boxes more thoroughly in the evening than during the early part of the day.

PSYCHOLOGICAL TESTS

As a result of experiments of a somewhat similar nature carried out elsewhere, it was thought possible to obtain a gauge of fatigue by means of psychological tests. This would have been very desirable because of the high degree of accuracy which the psychological method possesses, as contrasted with other less scientific methods of observation. Therefore, three tests were selected for this purpose. The first of these was the Woodworth-Wells Number Group Checking Test (a paper on which is printed over 100 groups of numbers), in which the inspectors were asked to check off all the numbers which contained both a "1" and a "7". This test is one which had been previously tried out and had proved valuable in the selection of inspectors.* The second test was a Dot Counting Test. A sheet of paper containing eighteen groups of dots arranged in irregular order was presented to each girl and she was required to count the dots in each group and put down the number. The third test was a simple one. It consisted of twenty-five lines of punctuation marks, numbers, and letters arranged in heterogeneous order. The task was to count only the dots in each line and put the number at the end of the line.

The next step was to select a group of inspectors to whom these tests should be given. Forty girls were selected. They were chosen partly on the basis of attendance, partly on the basis of length of service. Only girls who had been regular in attendance were chosen because it would have been obviously impossible to make a good fatigue study on subjects who were absent from their work a good part of the time. The girls were grouped in one part of the shop so as to facilitate giving the tests. The three tests were given to the forty girls at one time and without taking them from their work. The manner in which this was done was as follows:

Whenever the tests were given, each girl was provided with a little writing board, a pencil, and a copy of the tests numbered in their proper order. When these had been distributed and the inspectors had had an opportunity to get their boards into position, they were given the signal for the first test by means of a

*Details of the method by which psychological tests are developed and applied to particular kinds of work are to be found in the writer's book, *Employment Psychology*, The Macmillan Company.

shrill whistle. After two minutes the whistle was blown again, which meant, "Stop the first test and get ready for the second." After an interval of thirty seconds the second test was started in the same way and then the third test. The completed tests, pencils, and writing boards were then collected. The time occupied by this entire procedure was just about twelve minutes. Three people were required to carry out this work.

The three tests were given to the entire group of forty girls five times a day, first at 7.10 A. M., then just before 12.00 M., at 1.10 P. M., 4.40 P. M. and 5.40 P. M. They were given in this way for a period of three weeks, which means that a total of about 12,400 tests were given.

During the first week or two the girls improved so rapidly in the tests that no consistent effects of fatigue were apparent. After the first ten days, however, the effects of practice became less marked. The performances for the last nine days, therefore, were computed, with the results indicated in Figure 1. It developed during the course of the study that Test 3 was not printed clearly, and therefore the results in this test were abandoned. By referring to Figure 1 it will be seen that the percentage of errors bears a marked resemblance to the percentage of scrap found in the reinspection. The lowest number of errors occur at noon and there is a slightly higher percentage of errors at night than in the morning. However, the percentage of errors is in all cases extremely low, ranging from 2 per cent. to 5 per cent.

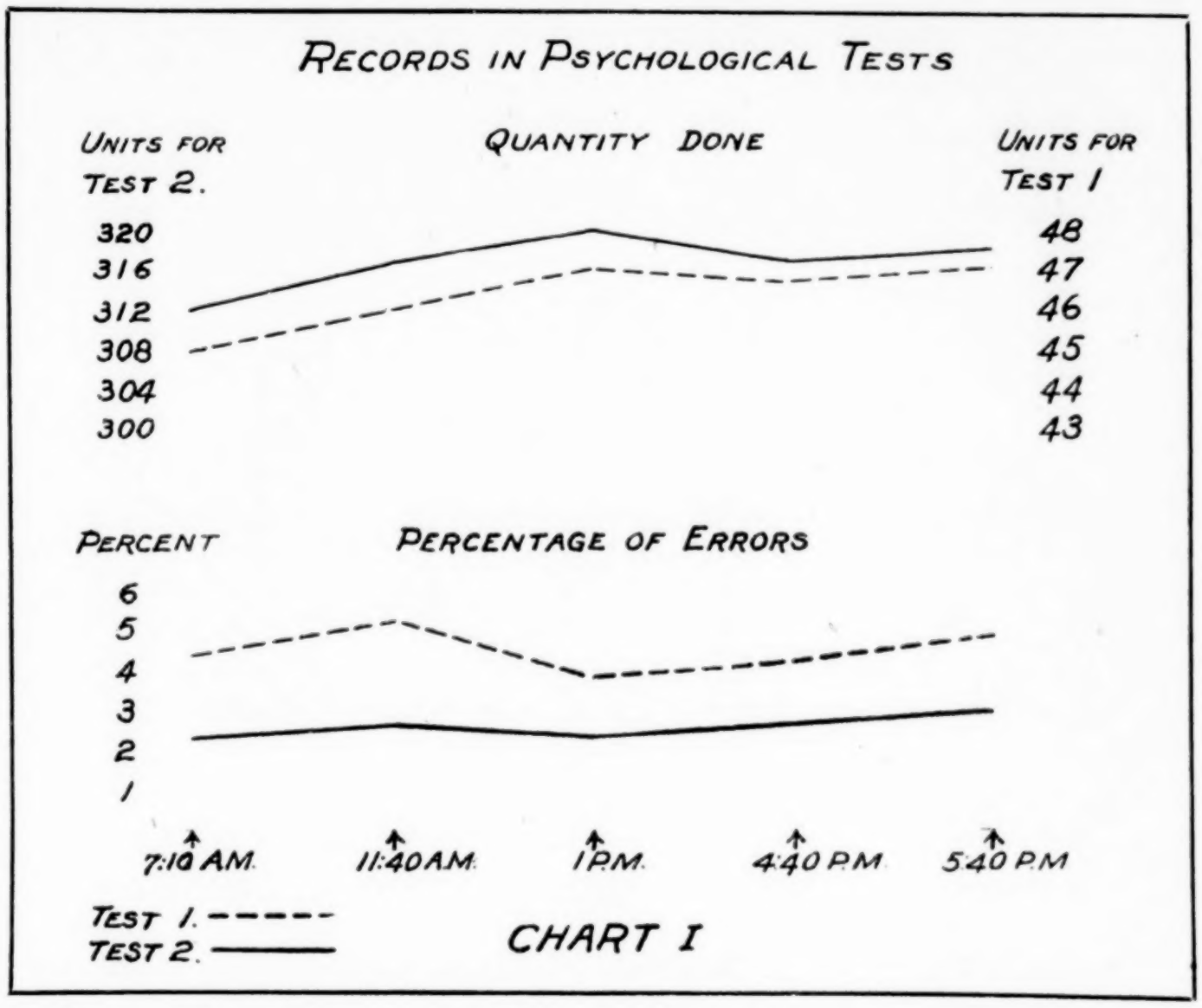

FIG. 1.—The curves represent the average performance in the tests of the entire group, at the various times of day indicated by the horizontal row of figures.

An entirely unexpected and unorthodox result is the record of the performances in the evening. Instead of a marked falling off in the quantity done at the end of the day, as might be expected, there is even a slight increase. This is entirely at variance with the popular notion of the effects of fatigue as well as with the more scientific theories on fatigue which have been advanced to date.

PRODUCTION AS AN INDEX OF FATIGUE

At the conclusion of the above study a careful production study was undertaken. This was done in order to determine the amount of work done at various times of day. Some thirty to forty experienced inspectors were timed, box by box, throughout the entire day for a period of three weeks. The weight of each box before and after inspection was taken. In this way it was possible to compute the average rate of production for each girl individually, as well as for the group as a whole, for each period throughout the day. The method adopted was to take the average rate of production for the entire group during each of the ten different hours of the working day. To be sure, not all boxes were finished on the hour. The boxes were

therefore attributed to the period within which more than half of the time taken fell. The rates of production for each of the three weeks studied, for the entire three weeks, and the average rate of production for the morning and afternoon are plotted in Figure 2.

It will be seen that the curves of production are quite consistent but it will also be seen that these curves do not bear out the traditional and hypothetical curves which have been presented as applying to work of this kind. According to the generally accepted notion of fatigue, the curves for work similar to inspection

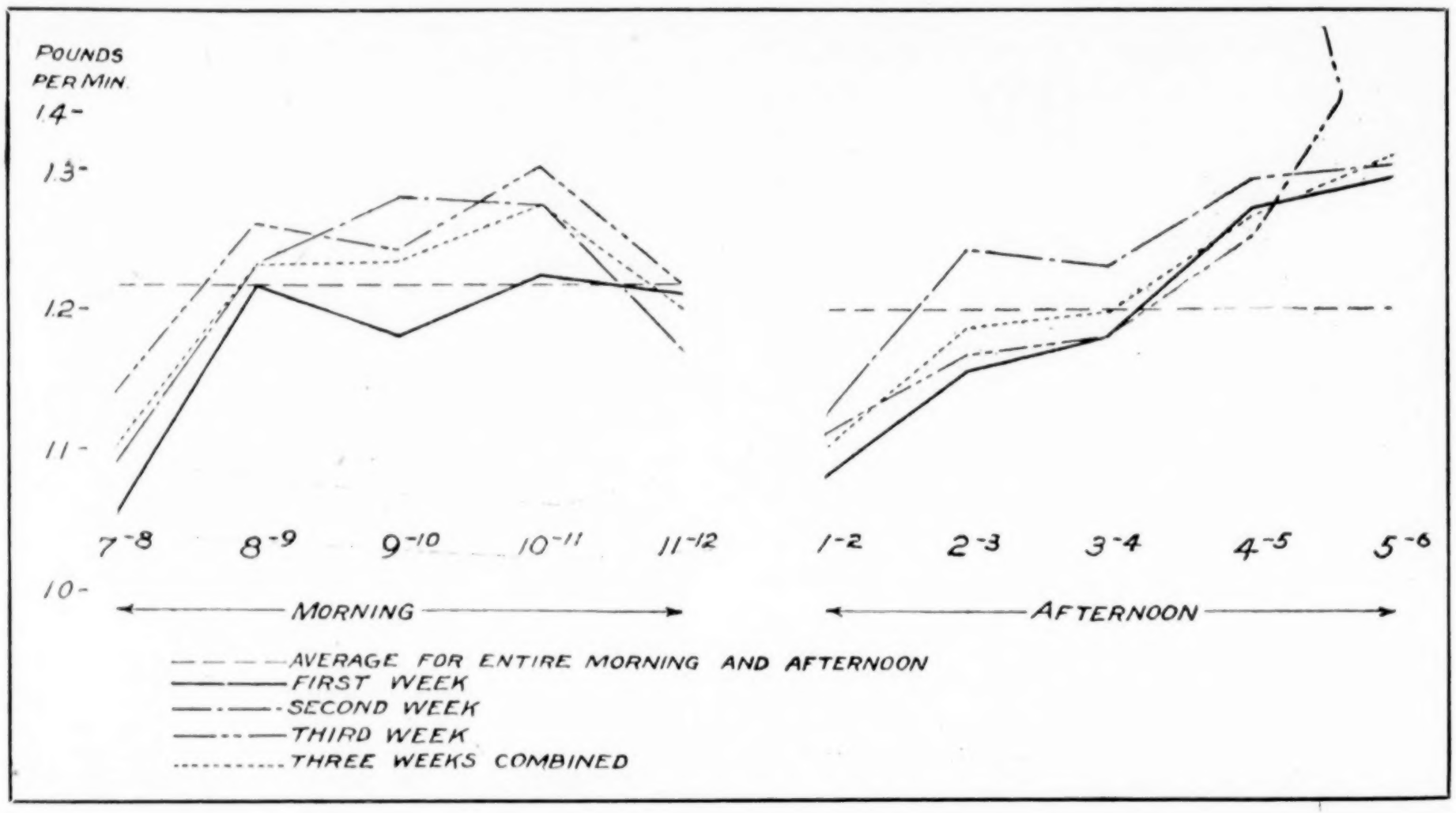

FIG. 2.—The uneven curves show the average rates of production (pounds per minute) of the entire group at the times of day indicated by the horizontal row of figures. The straight lines show the average rate of production for the morning and afternoon during the entire three weeks.

should be somewhat as shown in Figure 3, that is, a slight rise immediately after work has started in the morning and then a gradual falling off, then a considerable increase immediately after luncheon and a more sudden decline during the afternoon, with the lowest point at the end of the day.

No detailed, comprehensive study published up to the present time has demonstrated the correctness of these assumptions. The results of the present study certainly failed to bear out their soundness. In the first place, instead of a short rise in the morning and in the afternoon, there was a prolonged rise; instead of an increase in production immediately after luncheon, there was a decided drop; instead of a consistent decrease in production with the lowest point at the end of the day, there was an intermittent increase with the highest rate of production during the last hour of the day. The last fact is very striking in the face of all expectations and prophesies to the contrary. Superficially, it seems almost like a violation of physiological laws.

OBSERVED FACTS

In addition to the facts noted above, a careful observation was made of several contributing factors, such as temperature, ventilation, illumination, and general shop conditions. In so far as the factors observed could be interpreted, their effect should have been to retard production toward the end of the day. There was a slight increase in temperature—about two degrees—and a slight decrease in the quality of the light and ventilation. Although these observations led to several practical recommendations, they could not be connected with the changes in the quality and quantity of production without a great deal of ambiguity.

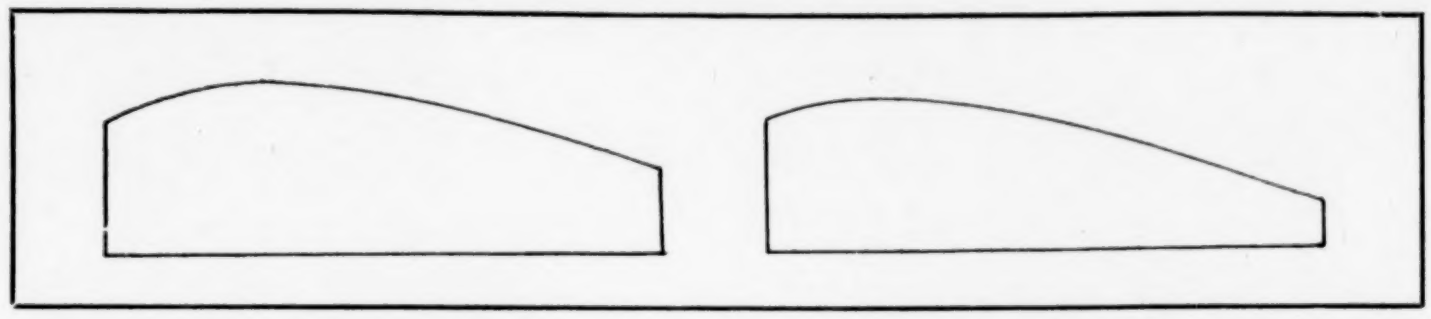

FIG. 3.—These curves indicate the traditional view regarding the rates of production during morning and afternoon for work like that described above. The horizontal distances indicate time of day; the vertical distances, rate of production.

CONCLUSIONS

a. *Reinspection.*—The reinspection described above showed that there was not enough difference in the quality of the work done at various times of the day to justify reducing the number of hours.

b. *Psychological Tests.*—The results in the tests, in so far as they were indicative, coincided largely with the results of the reinspection and production study. However, the variations in the quantity and quality of the work done in these tests were altogether too slight to justify using them as an index of fatigue. On the other hand, the variations due to practice were so marked as to make all other variations seem insignificant. This is not necessarily a repudiation of the psychological method, but rather an indication of the difficulties involved. It would seem that two-minute tests are entirely too short for reliability, even if carried on five times a day for a period of three weeks. Moreover, as has since been discovered in connection with the development of psychological tests for aviators, the human mind is able to concentrate for short periods even when it is almost on the point of exhaustion and render for such a time a performance which compares favorably with those done under the most favorable conditions.

c. *Production Study.*—The most conclusive results were obtained by this study. Various reasons may be given for the increase in production toward the end of the day.

(1) Each inspector desires to do a certain number of pounds of work per day, and as 6 o'clock approaches it becomes more and more necessary for her to speed up in order to make up for lost time.

(2) The offering of a 10 per cent. and 20 per cent. bonus for reaching a certain quota adds still further to the strength of this stimulus. Such a bonus produces an increase of exertion as the goal is approached, similar to the sprint of a runner when the end of his last lap is in sight.

(3) The effects of practice and rhythm are cumulative. As the day wears on the inspectors gradually hit a better and better pace. This is also the opinion of the foremen. In spite of these facts, however, it will be seen that the average production for the entire afternoon is slightly lower than the average for the entire morning. (See dotted black line.)

From the results of this study it cannot be definitely concluded that an eight or nine-hour day would either increase or lower the rate of production. In order to arrive at such a conclusion it would be necessary to try out the shorter day under identical conditions,—a course which it is practically impossible to follow. A year before the time of the present study it was found that forty shell inspectors did 3.2 per cent. less work per hour after the length of the working day had been reduced from ten hours to eight and six-tenths hours. This carefully checked up data, while not absolutely conclusive, shows at least that a shorter day does not *necessarily* mean an increase in the rate of production.

It was concluded that the ten-hour day *per se* did not produce enough fatigue among shell inspectors to prevent them from doing more work in the last part of the day than they did in the morning, directly after luncheon, or at any other part of the day. Whatever significance the psychological tests had, tended to corroborate the results of the production study.

This study was conducted without any preconceived theories regarding the relative merits of an eight or ten-hour day. Indeed, the writer does not entertain the notion that the results of this study or of any similar studies will have much effect on the final outcome of this problem. It is believed that, in the end, ethical consideration and not considerations of efficiency will decide what the length of the working day shall be. In this particular case efficiency was the prime consideration and it was therefore possible to make a practical study with this as the determining factor.

A STUDY OF FIFTY WORKERS IN TRINITROTOLUENE *

TRACY JACKSON PUTNAM, A.B.
and
WILLIAM HERMAN, A.B.

AS a part of a general survey of trinitrotoluene manufacture in the United States, we made a study of fifty partially selected men engaged in purifying and packing the material at a plant on the Atlantic slope, during the month of September, 1918. This survey was undertaken for the purpose of determining more exactly the symptoms of poisoning by the chemical, and its usual path of absorption and pharmacological action, as a step toward the early diagnosis and prevention of its harmful effects upon those handling it. In addition, it was hoped that the study of the manifestations of disease produced by a known toxic agent would help to throw some light upon the nature of clinically similar manifestations in diseases of unknown etiology. We were directed and much aided in our work by Dr. Alice Hamilton and Dr. George R. Minot.

The process in which our subjects were engaged was as follows: The crude acid trinitrotoluene, in large lumps, was shipped to the plant in barrels from the nitrating works. These barrels, usually covered with the material, were rolled by hand across a broad platform and dumped through a grating into an elevator, which transferred them to the great boiling tanks. In the tanks, the explosive was washed for some hours with hot water, stirred by steam jets, to remove the acid. The boiling was a clean process; little was spilled, and there was little dust or vapor. The inside of the tanks occasionally had to be cleaned, however, which involved much contact with the wet material and with the fumes.

When sufficiently washed, the molten trinitrotoluene was allowed to flow into large iron "eggs", from which it was blown by steam pressure into another tank in the graining-houses. The grainers consisted of low round iron vats, slowly but continuously stirred by a revolving dasher. There was a hood and draught chimney several feet above each. In these vats the hot chemical was allowed to cool and crystallize into a coarse yellow powder, the process taking about eight hours. This powder was then transferred with wooden shovels to barrels, which were loaded upon a "dinkey" train. The fumes were noticeable about the tanks while the trinitrotoluene was being poured out, but the shed in which they stood was open and airy. A good deal of material was spilled on the floor or sublimed about the walls. To remove it the entire building was scraped or hosed with live steam every few weeks, which produced so many fumes that it was considered a dangerous job. The barrels and utensils were caked with trinitrotoluene also and considerable dust was raised in handling them.

The barrels of powder were next transferred to the dumping-room on the second floor of another building, the packing-house. They were inverted on a grating over the floor and pounded to dislodge the contents. The powder was brushed through a revolving screen and descended through a funnel into shipping-cases, which were packed, weighed, and loaded by hand. Throughout the packing-house there was constant contact with the powder and much dust, but there were practically no fumes.

Waste and scrap from all over the plant was remelted and crystallized separately in a small open vat. This "pelleting" plant was practically out of doors; nevertheless, it involved considerable contact with trinitrotoluene and the fumes were heavy.

The men in the boiling and graining-houses worked in three eight-hour shifts; the packers, dumpers, and pelleters worked ten hours a day. About half the employees slept in the company's bunk-houses. There was a cafeteria not far from the works, where they could go for

*This work was undertaken under a grant from the National Research Council. Received for publication June 11, 1919.

lunch or could get food to take out. They were furnished with as much milk as they wished, free. Labor was very scarce, and the men seemed to prefer the work on smokeless powder to the much lighter jobs on "T.N.T."

THE SYMPTOMS OF MILD TRINITROTOLUENE POISONING

Reasonably comprehensive histories were taken from the workers whom we interviewed, concerning any symptoms possibly referable to poisoning which they had experienced since working with trinitrotoluene, their age, general condition, and habits of life in so far as these had a bearing upon their exposure to poisoning. In arranging the symptoms, we have adopted a modification of Livingstone-Learmonth and Cunningham's (1) classification. These authors, who, in an able paper, give a clinical account of the poisoning which includes practically all of the symptoms observed by later writers, group the symptoms as follows:

1. Irritative Symptoms:
   a. *Respiratory:* Nasal discomfort, sneezing, coryza, epistaxis. Smarting and watering eyes. Frontal headache, perhaps due to nasal obstruction. Sore throat. Tightness and pain in chest. Dry cough.
   b. *Gastro-intestinal:* Constant bitter taste. Spasmodic epigastric pain. Nausea and vomiting. Acid eructations. Constipation, then diarrhea; cramps and griping.
   c. *Cutaneous:* Various rashes.
2. Toxic Symptoms:
   a. *Gastro-intestinal:* Bilious attacks, nausea, vomiting, anorexia, constipation, jaundice. Dull pain behind ensiform.
   b. *Circulatory:* Faintness, giddiness, flushes, pallor, cyanosis, bradycardia, palpitation, air-hunger, swelling of extremities, non-traumatic bruises.
   c. *Nervous:* Drowsiness, apathy, loss of memory, blurring of vision, peripheral neuritis. As a terminal event, delirium, coma, convulsions.
   d. *Special:* Irregular menstruation. Dark, scanty urine, dysuria.

Symptoms apparently referable to irritation of the respiratory system were not prominent in our series of cases, and did not seem to appear as early as in some groups which have been studied. Eight men complained of a feeling of tightness in the chest, usually accompanied by cough, coryza, or sore throat. Smarting and watering of the eyes occurred in seven cases. Some of these men had no other symptoms; others were fairly sick. The respiratory discomfort in itself was not serious.

The symptoms of gastro-intestinal irritation—bad taste in the mouth, anorexia, diarrhea, cramps, constipation, nausea, and vomiting—appear early in those exposed to trinitrotoluene. Fifteen reported a loss of appetite, and twenty-five a bitter taste in the mouth. Nineteen had had diarrhea, ten constipation, and five abdominal cramps. All of the above mentioned symptoms had appeared during the first three weeks of exposure. Ten of those affected with these milder symptoms had experienced attacks of nausea; and seven, attacks of vomiting. The nausea and vomiting usually appeared from ten days to two weeks after the milder irritative gastro-intestinal symptoms had been experienced, and apparently indicated a much more severe form of poisoning as they were almost always accompanied by symptoms referable to other systems. The physical examination and laboratory findings usually confirmed this impression.

Thirteen men reported cutaneous irritation, coming on during the first three weeks of exposure, usually during hot weather. We saw a few cases of this dermatitis, which will be described later. All of the men in this group had had the milder symptoms of gastro-intestinal irritation during the same period but, with one or two exceptions, they did not seem very sick.

The importance of evidences of renal irritation does not seem to have been brought out by earlier observers. Eight of our men gave a history of polyuria, which was marked in some cases; and of these, six had urgency of micturition as well and two a possibly suggestive lumbar pain. These symptoms did not appear in less than two weeks in any of our cases, and were usually accompanied by other evidences of poisoning. The scanty urination reported by Livingstone-Learmonth and Cunningham was not seen.

The "toxic" symptoms may be divided into the gastro-intestinal, the circulatory, and the nervous. Whether they are really due to the toxic effect of the chemical on these systems is, perhaps, open to doubt. We rather believe that the majority of them may be explained by the loss of oxygen-carrying power of the blood, which

is indicated by the laboratory examinations. That true degeneration can be caused in parenchymatous organs, however, is shown by the occurrence of atrophy of the liver in the fatal cases of poisoning.

The only symptoms which appeared to us definitely referable to toxic action upon the digestive tract were those which might indicate liver involvement: pain and tenderness in the right epigastrium, especially when accompanied by nausea or vomiting. Five workers reported epigastric pain, and physical examination revealed a palpable liver in two of them; both were seriously poisoned men. The other three had the symptoms of mild poisoning only. Liver involvement is, of course, the most dangerous effect of trinitrotoluene poisoning, except perhaps the rarer aplastic anemia.

The circulatory symptoms, dyspnea and dizziness, were prominent in our series, being present, usually together, in fifteen cases. All of the men so affected had previously had the milder, and some, the severer gastro-intestinal symptoms. Practically all showed macroscopic hemoglobin change, and red cell changes in the stained blood smears.

The nervous effects may be divided into those apparently central and those apparently peripheral. Of the cerebral effects, drowsiness or easy fatiguability has been noted by all observers. They occurred, usually together, in sixteen of our cases, usually the more severe ones, and varied from a weakness in the legs when climbing stairs to a constant depression. Headache was reported by about the same number of patients, but often with very few other symptoms. Dizziness was spoken of by sixteen men, and was marked in some instances. It was associated with headache in about half the cases. The cerebral group of symptoms came on rather later in our series than in some others—rarely before the second week.

The manifestations of the "peripheral neuritis" of Livingstone-Learmonth and Cunningham were extremely interesting. The most important was a curious "tired pain in the back of the knees," almost always described in those words. It occurred in ten men. Twitching of muscles, especially of the legs, was reported by four of our subjects; other workers in this same survey have also had cases of it.

Practically all of the men showing marked nervous symptoms were deeply cyanosed and smears of their blood showed red cell changes. We are inclined, therefore, to believe that such symptoms may be regarded as secondary to the blood changes.

From the above findings taken in connection with those of other workers, we have concluded that symptoms confined to the gastro-intestinal tract are of little consequence when found alone; that the same is true of irritative skin lesions; that symptoms of blood involvement show a marked stage of intoxication, whether occurring alone or accompanied by other manifestations; and that renal, and particularly liver manifestations, are indicative of a more profound and dangerous intoxication.

The epistaxis, bradycardia, air-hunger, palpitation, swelling of extremities, ecchymosis, scanty urine, blurred vision, loss of memory, convulsions, and coma, spoken of by the English writers (1), were not encountered although asked for. Six men had had practically no symptoms; of these, three had worked less than a week, and one was a foreman, who was but little exposed.

FINDINGS ON PHYSICAL EXAMINATION

The appearance of every one of the men who actually handled trinitrotoluene was striking, as all who have seen them remark. Except for two or three of the foremen, who carefully avoided all contact with the powder and observed most scrupulous cleanliness, every worker's hands were stained an orange color, varying from a delicate lemon to a deep ochre. Merely picking up a single fistful of the powder left a perceptible yellowing, which persisted for a day or two in spite of soap and water, leaving the skin rather hard and brittle, much as will a very slight nitric acid burn. Possibly a part of the stain is due to retained acid. Gloves of leather or canvas did not prevent the soiling of the hands, for the fine powder always sifted in around the wrists. The hair and beards of many of the men, especially of those with light complexions, often took on a reddish chestnut brown. Often the face, upper arms and chest would be lightly yellowed from deposited

dust. Where the skin was not stained, it was usually pale and sallow; and especially in those most saturated with the stuff, the whole face had a characteristic wizened, grayish-yellow look. The Medical Research Committee of the National Health Insurance (Great Britian) (2) mentions such an appearance as being of value in the diagnosis of serious poisoning and, in general, the degree of pallor did seem to us to correspond roughly with the severity of the case. We made special note of the grayish-yellow pallor in eleven cases, and none of the white men whom we considered the sickest were without it; in the negroes, of course, it was difficult to make out. On the other hand, several of those in whom it was marked seemed otherwise well.

More significant, as the English writers agree, was the color of the mucosae. In only ten of the subjects was the color noted as within normal limits; of these, two had been at work for only one day, and one was a foreman who came but little in contact with the material. In thirty-three a distinct bluish coloration was made out, varying from a slight purpling to a pale slate gray. The men whose lips showed such a slatey blue were as a rule the sicker ones, but by no means invariably. Five looked merely pale, without any cyanosis, but an examination of the blood showed that they were not distinctly more anemic than the rest.

A slight yellowing of the sclerotics, apparently not due to jaundice, but to a uniform deposit of fat, was observed in all of the negroes examined except one, and we came to regard it as not abnormal in that race. Slight jaundice occurred in two white men, one of whom had a palpable liver and other signs which we considered to indicate severe poisoning, while the other appeared but little affected. True jaundice is, of course, a prominent feature in all the later cases of liver degeneration and seems, therefore, an important sign in all.

Panton (3) remarks that many of the men he examined who had not begun to work on trinitrotoluene, had a slight yellowing of the sclerotics, which he attributed to constipation. Both he and Pillman (4) believe that little weight can be attached to mild jaundice in the diagnosis of trinitrotoluene poisoning, but perhaps there may be a difference of opinion as to what constitutes definite jaundice.

Nine cases of dermatitis were seen. The eruption consisted of rather close-set, discrete, pin-head sized papules, usually rather red. Its favorite location was the extensor surface of the forearm, though it sometimes occurred on the back of the hand and about the face. The lesions itched, but not severely. The pompholyx type of lesion, crusting, and "lichenification," spoken of by the English writers (1) (5), were not seen; however, all those who have reported dermatitis agree that it is worse in hot weather and the temperature was moderate all through our period of observation.

Tenderness and spasm in the epigastrium was found in eight cases. In three of these, it was probably due to passive congestion of the liver, since valvular disease of the heart was found, or possibly the circulatory disturbance made the organ more susceptible to poisoning. In some of the remainder, the tenderness may have been neurotic in nature, but, on the whole, it was most marked in those who had clear symptoms and signs of poisoning elsewhere. In two of the men, the liver was distinctly palpable below the costal margin, although no cardiac lesion could be found. An enlargement of the liver is a most definite evidence of degeneration and should be a signal for removal of the man from work. Both of our cases had many other symptoms of poisoning.

For the rest, the physical examination was essentially negative. The tongue was usually clean. The teeth were bad, as a rule. In nine men, valvular disease of the heart was found—a rather high incidence, due perhaps to the fact that many had been refused for the army. The lungs were normal in practically all cases. The knee-jerks and pupillary reactions were within normal limits in every case. The pulse ranged from 62 to 104; its quality was not remarkable. The respirations per minute were from 12 to 28; the higher rates occurring in cases of heart disease. The temperatures were all between 97° and 99°F. Blood pressure was apparently unaffected by the substance; the highest systolic pressure was 155 mm., the lowest 105 mm., and the figures varied, in general, with the age of the subject. On two occasions, we took the blood pressures of

a series of fifteen men before starting work and again at the end of the shift. The average of the former readings was 119.5 mm., systolic; 83, diastolic: and of the latter, 120.6 mm., systolic; 84.4, diastolic. Examination of the blood pressures of three men just before and just after steaming out a tank—a very dirty job—also showed no noteworthy variation.

LABORATORY FINDINGS

A sample of urine was obtained from almost every subject and, whenever possible, two samples, one passed in the evening, and one in the morning. The conditions under which we had to work made it impossible to collect any twenty-four hour amounts. The color, reaction, and specific gravity were noted in most cases, and the Webster test (6) for trinitrotoluene products was done as routine. In a good many samples albumin was tested for by the nitric acid method and sugar with Benedict's solution; in a few, the sediment was examined. Ehrlich's test for urobilinogen was done, or the sulphates were determined by the centrifugal method.

The Webster test was considered the most important part of the urine examination by the English workers, since it is characteristic and constant in practically all cases of poisoning. It consists in shaking together 10 c.c. each of the urine, 20 per cent. sulphuric acid, and commercial ether; allowing the liquids to separate, and drawing off the aqueous layer. The ethereal solution is again shaken with 20 c.c. of tap water, and again decanted. To it is added 5 c.c. of a 5 per cent. solution of caustic potash in denatured alcohol. An orange or purplish coloration, changing to a dirty brown, is a "positive" reaction, and the relative intensity of the reaction may be indicated by calling it from one to five plus. The color is much like that obtained by making alkaline a dilute solution of trinitrotoluene in alcohol; moreover, the crystals which we obtained by allowing an ethereal extract of a good "positive" urine to evaporate on a slide had a form very similar to, if not identical with, that of pure trinitrotoluene crystals. Moore (2), however, declares that the substance in the urine is a reduction product of trinitrotoluene. The urine before being acidified gives no coloration with alkalies, unless it has been contaminated. The test is practically specific and can be made absolutely so by adding caustic potash to an ethereal extract of the unacidified urine, as its originators observed, to detect contamination from the subject's hands or clothes, or by microscopical examination of the crystals deposited from ether. While such precautions are seldom necessary, it must be remembered that a case has been reported (7) in which a false reaction was given by rhubarb administered to the patient, and some of the other anthracenes or other substances might have a similar effect.

We attempted to devise a method for making the Webster test quantitative by subjecting a standard solution of pure trinitrotoluene to the same series of manœuvres used in the usual test and using it as a colorimetric standard. We found that a 0.1 per cent. alcoholic solution was stable and that more dilute standard solutions in water could be easily made from it by adding potassium hydroxide in excess. Such alkaline solutions were fairly comparable with the ether-alcohol-water solution obtained as an end result of the Webster test on urine if the latter were diluted two or three times. They faded rapidly, however; and other factors, such as the evaporation of the ether, the presence of particles in suspension, and so on, made the technique so formidable that we abandoned it after a few trials. We determined, however, that a "three-plus" urine contained about 0.03 per cent. trinitrotoluene; what the twenty-four hour amount may be, we have, of course, no means of knowing. If it were ever essential to quantitate trinitrotoluene in urine, a modification of the iodine method for nitro derivatives might be used (8).

The Webster test is, then, an index of the amount of trinitrotoluene which is being excreted in the urine. Moreover, the kidneys appear to be the chief, if not the only path of excretion of the material. The stools from three of our severest cases were negative by the Webster test, which was not the experience of the English observers (5); and although workers speak of seeing pink spots under the arms of their underclothes after laundering, suggesting elimination in the sweat, the amount thus disposed of cannot be very

considerable. The test may be negative in one specimen of urine and very positive in a specimen passed eight or ten hours later; it is usually much more positive in samples made at the end of the day's work than in those voided in the morning; which indicates that the trinitrotoluene is usually disposed of rather rapidly.

If, then, we assume that the severity of the symptoms produced by the chemical is proportional to the amount present in the body, we should expect the severest cases to be associated either with a very positive Webster, indicating a high rate of absorption, or with a slight or negative Webster, indicating faulty excretion. But we were unable to make out clearly any such relation. On the whole, the men most affected by the trinitrotoluene had higher Websters than the others. But some of our severest cases showed a less intense Webster than others practically free from significant symptoms or signs. The men who kept their hands clean gave slight or negative tests; most but not all of those who were personally dirty had high tests.

The color of the urine was noted as darker than normal at some time in thirty-nine of the cases. It ranged from a scarcely abnormal amber to a fairly deep red, like port wine, and some men gave a history of having noticed a difference in the color. The intensity of the color increased on standing but was not influenced by the reaction of the urine. We were not able to account satisfactorily for the coloration. The specific gravity tended to be high, up to 1.038 in two cases, and usually between 1.020 and 1.030. Both color and specific gravity varied directly with the intensity of the Webster test in most instances.

An unexpected finding was that Benedict's qualitative solution was reduced by those urines which gave an intense Webster. In four specimens in which reduction was pronounced, however, the addition of yeast caused no evolution of gas or change in specific gravity after incubating; and reduction still could be obtained. We were unable to reduce Benedict's solution with weak solutions of alkaline trinitrotoluene, and we, therefore, came to the conclusion that the oxidizable substance was probably glycuronic acid. The urinary sulphates, which we expected to find increased from analogy with the conditions in phenol poisoning, were well within normal limits in the four instances in which they were determined.

For the rest, the urine examination was not remarkable. The reaction was usually acid. Albumin was present in small amount in three cases, absent in fourteen; it did not appear to have any connection with poisoning. The sediment was negative in the seven cases in which it was examined. The test with Ehrlich's reagent gave no evidence of the presence of urobilinogen, which the condition of the blood led us to believe might be present. Bile was never found.

Stool examinations were done in three of our most severe cases but we were unable to demonstrate trinitrotoluene in any of the specimens. This is not in accord with the findings of the Ministry of Munitions Committee (5).

Several investigators have suggested that the condition of poisoning is associated with an acidosis. To test this point, we tried Sellard's test on five of our more severe cases. Ten grams of sodium bicarbonate are administered, and the urine collected two hours later; if it is acid in reaction, the alkali reserve of the blood is probably reduced. Four of our men showed an alkaline reaction; one an acid reaction. We were inclined to attribute the latter result to a failure to follow directions, and to believe that an acidosis is not a feature of the earlier stages of poisoning.

THE BLOOD

Of all the laboratory examinations, we believe that that of the blood gives the most definite evidences of the poisonous effect of trinitrotoluene and agrees most satisfactorily with the subject's condition clinically. The importance of the study of the blood is well brought out in Minot's analysis of 233 cases (9), among which ours are included and to which we refer the reader. Our series contained representatives of all of his classes.

THE PATH OF ABSORPTION

The determination of the path of absorption of trinitrotoluene is an essential step toward devising intelligent measures of preventing poisoning. In investigating it under working conditions, one thinks first of the inhalation of fumes and dust. The sweetish, irritating odor is perceptible all

through the grounds of the plant. Both purifying and graining the material involve the use of heat and the tanks are by no means tight. The material is transferred in a molten condition from one building to another by steam pressure, and at the outlet and at any leaks or holes in the pipes it may be seen to sublime out in flat sheaves of glistening, yellowish, acicular crystals. The workmen, also, believe that inhalation of finely divided material is productive of poisoning. One veteran at the trade always wore a rubber filter, which he provided himself. The most feared procedure was cleaning out the bottoms of the great tanks in which the crude product was boiled. The heat, moisture, and smell in them was almost overpowering and many of the men refused point-blank to enter them. We heard from several witnesses stories of how men would faint and grow blue in the face during the process of cleaning the buildings, which was done by volatilizing and melting with live steam any of the explosive that had been spilled. Our most severe cases came from the screening and packing-house, where the air seemed filled with a fine powder; and from the pelleting-plant, where waste material was recrystallized in an open vat.

We were, however, forced to the conclusion which Moore and his co-workers (10) had already reached, that poisoning by way of the respiratory tract rarely, if ever, occurs. The amount of trinitrotoluene indicated by a strongly positive Webster seems too great to have been absorbed through the lungs alone. One of us remained in one of the boiler tanks for a half an hour during the process of cleaning, which should constitute a severe exposure to fumes, without feeling any symptoms or producing a Webster in his urine. We were led, therefore, to repeat some of Moore's simpler experiments, namely, those of examining the air of the different buildings for trinitrotoluene. We constructed an apparatus to aspirate air through a small quantity of alcoholic solution of caustic potash, and thus examined 50 litres each from the worst corners of the graining-house and the screening-room, respectively. No change of color was produced in the alkali, although 0.005 mg. of crystalline trinitrotoluene is easily detected in this manner. The sensations produced by the smell were probably imaginary. The undoubted cases of syncope occurring during the "steaming-out" may well have been due simply to heat exhaustion. Or it is possible that the combination of heat and moisture favors absorption of the material, or that it produces symptoms in an already poisoned man.

The most important path of absorption is undoubtedly the skin, although a considerable amount may sometimes be taken in by mouth also. While we were unable to repeat Moore's ingenious and elaborate experiments, our observations were all in accord with this theory. The dirtiest men were, on the whole, the sickest; and none of the foremen who took pains to keep their hands clean showed any signs or symptoms at all, although they were often exposed to the fumes. Moreover, the danger from dust seems to be best explained in such a manner, for the clothes of the men who worked in the dustier parts of the plant were constantly saturated, and, since many of them slept in the same outfit, the chance of absorption was great.

Ingestion by mouth is also probably of some importance in the causation of poisoning. The danger seems to lie not only in eating lunch on the premises or with dirty hands, which is obviously dangerous, but also in chewing tobacco handled with fingers loaded with the chemical. The practice of chewing is very common, since the men cannot smoke, and some believe it is a prophylactic, in that it conceals the smell and taste and encourages spitting.

The effect of alcohol upon workers in trinitrotoluene is an interesting one, already remarked by several observers. Some men were able to drink without noticing any unusual symptoms, but from three or four, normally by no means easily upset, we heard some remarkable tales. The stories were much alike; after taking one or two small drinks, a man would feel dizzy, and often turn blue and faint, his pulse and respiration becoming rapid. There was also a rumor that if a man came to work the day after a "party," he was sure to get poisoned. We are inclined to believe the substantial truth of these stories, and to think it possible that alcohol being an excellent solvent for tri-

nitrotoluene, favors the absorption from the skin or perhaps mobilizes it in the body. A similar explanation may be advanced for the effect of steam in bringing on symptoms. Moore found that the drug was absorbed much more rapidly by oily hands. At any rate, there is a very general and very healthy belief among the men that "T.N.T. and whiskey don't mix."

Practically all observers agree that more cases of poisoning occur in warm weather than in cold, as Rice's (11) interesting tables illustrate well. We did not have a chance to verify this for ourselves, as the weather was temperate during our entire stay at the plant; but from the histories, the skin eruptions had been more severe in the height of summer.

We could not make out any racial idiosyncrasies to trinitrotoluene, although we had opportunity to observe whites, negroes, Haitians, Cubans, and Porto Ricans. No women were employed in these trinitrotoluene works.

CONCLUSIONS

1. The symptoms of mild trinitrotoluene poisoning may be grouped as follows, approximately in order of their usual appearance:

   (a) Those apparently due to gastro-intestinal irritation — distress, diarrhea, loss of appetite, nausea, vomiting.
   (b) That due to cutaneous irritation —dermatitis.
   (c) Those due to alteration of the blood—dyspnea on exertion, dizziness, headache, fatigue, pains in the legs, sleepiness.
   (d) Those due to renal irritation—urgency and frequency of micturition, lumbar pain.
   (e) Those due to degeneration of the liver—pain and tenderness in the right epigastrium.

Many of the above symptoms may doubtless be produced in more than one way; thus, fatigue may be due to general intoxication, and gastric symptoms may be secondary to degeneration of the liver.

2. A palpable, tender liver is necessarily an ominous symptom.

3. The characteristic discoloration of skin, and the cyanosis, give a general indication of the extent of absorption.

4. The Webster test is practically specific for the presence of altered trinitrotoluene in the urine, and is a useful measure of the extent of absorption; otherwise, it appears to have little prognostic value.

5. The altered trinitrotoluene is excreted in combination with some body (probably glycuronic acid) which reduces Benedict's solution but is not fermented by yeast.

6. No acidosis could be demonstrated by Sellard's test.

7. No "nitrite effect" upon blood pressure was found.

8. The skin is the chief avenue of absorption and preventive measures should be aimed largely at avoiding contact with the material.

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SYPHILIS, AN INESTIMABLE FACTOR IN INDUSTRIAL INEFFICIENCY *

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THAT syphilis is a moral corrosive has been commonly understood, that it has been a menace to personal and public health is a matter of common knowledge; but that it could be regarded as a prolific source of industrial inefficiency has just dawned upon the profession. Too little attention has been given in the past to this disease by the industrial physician and the profession as a whole. Surely it is high time that active measures be taken against an enemy that fills our insane asylums, causes thousands of stillbirths, stands as a large factor in all of the killing diseases, and causes a sufficient decrease in the efficiency of the working world to rank it as one of the most important economic problems in industry.

There are several possible reasons for our past inaction. First, syphilis has always been associated with immoral sexual relations, and little attention has been given it as a public menace. Second, we have very little knowledge of the prevalence and extent of the disease. Third, through a false sense of modesty, it cannot be given the publicity it deserves.

Difficult as it is to gather data, these few statistics will serve to emphasize the immensity of the problem with which industrial physicians are confronted. The city of New York has for the past few years made venereal diseases reportable. In the fourteen weeks from July 4 to October 3, 1914, 25,633 infectious diseases were reported. Syphilis stood first, with 6432 cases, or 28 per cent.; Tuberculosis second, with 5525 cases, or 21 per cent.; Diphtheria third; Measles fourth; and Scarlet Fever fifth. This report, however, shows only those cases that were reported, probably 50 per cent. It is inconceivable then that a disease of such extent is not a cause of industrial inefficiency. In the army during the fifty-three weeks ending September 27, 1918, there were reported 178,204 venereal diseases. About 16 per cent. or 27,000 of these were syphilitic. During 1917, 750,000 days were lost to the army through venereal disease, but in the year 1918 the loss reached the alarming total of 2,067,000 days. The fact that has been both encouraging and surprising from the army point of view is that 85 per cent. of the soldiers so afflicted were already infected when they entered the service.

Colonel Vedder in his recent book *Syphilis and Public Health* says that 20 per cent. of the young adult population from which the army is recruited, in peace time are luetic, and he estimates that 5 per cent. of our young men in college are infected. He says "Since syphilitic infection is so common and so productive of disability, and has so far evaded sanitary control, it is believed that syphilis is a greater menace to the public health than any other single infectious disease, not even excepting tuberculosis." Osler has recently said that of the killing diseases, syphilis ranks third or fourth. He estimates the actual annual deaths at 60,000, which makes it rank first among the infections. Leredde estimates that syphilis kills 25,000 each year in France.

Some careful investigations have been made on the incidence of syphilis among the tuberculous of the country, and it has been estimated that between 20 per cent. and 30 per cent. of those so afflicted also suffer from lues. It has been shown many times to be an important predisposing factor in tuberculosis. In the last few years at a number of the general hospitals in larger cities, Wassermann tests have been made a routine part of the examination. From a study of figures estimated in this way, it is fair to state that between 20 and 30 per cent. of the patients in the average hospital are infected with syphilis. In view of these figures, can we say that syphilis is on the decrease?

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The campaign against this disease directly concerns industrial physicians. Syphilis is a powerful factor in industrial inefficiency. While the acute primary and secondary lesions are a possible source of infection to hundreds of innocent employees, it is the chronic tertiary untreated or insufficiently treated cases that work havoc in industry. They are the potential causes of accidents to themselves and to others. When injured, their disability is always prolonged. They are generally chronic absentees—inefficient employees—and a source of trouble at all times.

The following case records clearly demonstrate the necessity of ferreting out all old luetic cases and placing them under proper treatment.

CASE 1.—Sam W., aged 42, Norwegian by birth, was one of our most constant visitors at the hospital. He was of a sullen, morose disposition, and there was constant friction between him and his foreman. Previous to his employment in this industry he had been a sailor, and during that life had suffered a fractured spine by falling from a mast. After working for us a short while a box accidentally fell from a loft, injuring his back. He was taken to the hospital and a careful examination made, which disclosed nothing but his old fracture. He recovered and returned to work, and was a fairly satisfactory employee for several years. Then he began to be a visitor at the hospital. He was certain the injury to his back was responsible for the pains in his back and legs. He was given a thorough physical examination and it was found that his knee jerks were sluggish, a Romberg sign was present, and his pupils failed to react. A Wassermann was done on his blood and spinal fluid, and both found positive. He was immediately transferred to our clinic and energetic treatment begun. While his tabes is not cured, Sam is a much improved man. He takes his treatment conscientiously, his back and leg pains have disappeared and his efficiency has improved 60 per cent.

CASE 2.—B. R., aged 44, a foreman in one of the busiest departments, became so inefficient in his work as to attract the attention of his manager and his fellow employees as well. From a bright, active, energetic foreman, he had suddenly changed to an absent-minded and careless workman. Important orders were forgotten, and worry over his condition was evidently making things worse.

Knowing that something was wrong, his manager sent him to the doctor's office for a complete examination. Several months previously, while on his vacation, standing on his front porch one evening, without any warning he fell over, became unconscious, and remained so for a short time. When he recovered consciousness, he knew nothing of what had happened. After a few days' rest in bed he recovered and returned to work. The incident bothered him a little, but not to the extent it was destined to when he had several more similar attacks. His family physician pronounced it "nervous exhaustion", but he did not improve under treatment. He hesitated about consulting the company physician for fear of losing his job—a fear that had no basis. He was thoroughly examined, a Wassermann was done as a routine measure and proved to be very positive. His spinal fluid was then tested and also proved to be positive. He was told of his condition and then admitted having had an initial lesion twenty years previously, for which he had taken little or no treatment. Anti-syphilitic treatment was begun at once, and has been continued ever since. His health is very much improved, he has had no more attacks and his work has returned to better than its previous standard.

CASE 3.—B. C. (female), aged 18, was a thin, poorly nourished girl. While working in the millinery department trimming hats, she scratched the back of her hand with a piece of wire. She thought nothing of it, and did not report to the doctor's office. A few days later she developed a lymphangitis of the hand and forearm. She was taken to the hospital and the condition rapidly subsided under hot dressings. She was sent home, and a few days later had a recurrence of her trouble. It again subsided under proper treatment, but did not remain so long. After about three weeks of this disappearance and reappearance, a Wassermann was made. It proved to be very positive. The girl showed other unmistakable signs of congenital syphilis. Anti-luetic treatment was begun at once and she began to improve. The treatment helped a great deal, but this girl was at and away from work for two years before she became well enough to be an efficient employee. This was a case of congenital syphilis complicating a very simple infection. Practically two years of employment were lost, a rather expensive case for the industry.

CASE 4.—H. G. (female), aged 20. A helper in the restaurant was sent to the doctor's office by her manager because of a suspicious cold sore on her lip. Examination showed the sore to be simply teeming with spirochetes. Careful inquiry into her history disclosed the fact that she had been married two months previously. I explained to her the necessity of talking things over with her husband. He consulted me at my office, and I found his mouth and throat full of mucous patches. He had had the infection for a year, but had taken no treatment because he could not afford it. The girl was laid off and she and her husband were transferred to our industrial clinic for treatment. Ignorant as this girl was of the nature of her infection, she was a possible source of trouble to hundreds of innocent fellow employees.

These and countless other cases I could enumerate ought to be enough to make the industrial physician realize that this nation-wide campaign against the venereal diseases is his fight. The program here outlined for industrial physi-

cians to follow is, in many features, similar to that carried out by the army in the war. Under this program the annual venereal disease rate in the army has dropped from 83.6 per 1000 in 1915 to 20 per 1000 in 1918.

The program embraces four parts:

1. Educational and social measures similar to those carried out by the Commission on Training Camp Activities. This should include talks, lectures, and the distribution of pamphlets concerning the disease; personal talks to the girls by a woman physician, the chief nurse, or a well-informed social worker, and talks to the men by the chief surgeon. These talks, if they are of the right kind, are of a great deal of value. Exhibits of posters, lantern slides, and moving pictures can all be used to advantage. The film *Fit to Fight* can be borrowed from the Public Health Service at any time. Anything that diminishes sexual desires should be encouraged. Baseball teams, track athletics, basketball, and bowling teams should be organized. These measures have been of immense value to the army. They should also benefit our civil population.

2. Prophylaxis after exposure. It is unreasonable to expect and decidedly impracticable for industries to maintain prophylactic stations. They will, in the near future, be installed in every industrial community by the Public Health Service. It is our duty to teach men that once they are exposed, prophylaxis does protect in the great majority of cases, if taken immediately after, or within six hours of exposure—the quicker the better. This treatment includes scrubbing well with soap and water, washing with a mercuric chloride solution, dilution 1:2000, a thorough rubbing with 33 per cent. calomel ointment, and an injection of 2 per cent. protargol to prevent gonorrheal infection. In the army, of 23,702 men taking prophylaxis over a period of twenty-two weeks only 1 per cent. developed a venereal disease, although many did not apply for many hours after exposure.

3. Medical examination of employees. By a careful examination of all male and female applicants for work, and the supervision of the health of the old working force at every opportunity, many cases of syphilis will be discovered. Male applicants can be stripped and a careful examination including Wassermann test done on all suspicious cases. Females, of course, cannot be examined as thoroughly, but a careful inspection of the mucous membranes and skin can be made, Wassermann done, and, if the industry has a female physician, vaginal examination made when it seems necessary.

The outfit for careful examinations of initial lesions can be installed in any laboratory at a cost of not to exceed $25. This sum will buy a dark field illuminator and a good carbon light, which are all the equipment required in addition to a microscope. The technique for examination of spirochetes is easily mastered and this examination should be made of all lesions that bear any resemblance to lues. The day of waiting for secondaries to appear before administering treatment is past. Suspicious cold sores of several weeks' duration should always be examined, especially if there is accompanying glandular enlargement. In two years' time twelve lip chancres in girl employees in one industry were discovered.

The officials in industry must be taught and encouraged to adopt a broader policy than has heretofore been followed. Too often in the past employees have been dropped from the pay roll the moment they showed signs of venereal trouble. This tends to discourage physician and patient. Employees, exposed and afraid to report to the reputable physician in charge of their health, evade him and consult the advertising quack. They are bled financially, poorly treated, if treated at all, and then left when their money gives out to go untreated, worrying over their expended money and the fear of the disease. This one factor alone is a cause of inefficiency.

The industrial physician in his daily work comes in contact with such a large number of people that if he is at all the right kind of man he is in a position to do untold good to a large number of them. He must have the confidence of the employees, but once he has that it will be surprising to him the number of latent and chronic cases of syphilis he can unearth.

4. The Treatment of Syphilis. When once discovered, what should be done with the disease? J. H. Blaisdell of Boston selected sixty cases that came to him

in the infirmary and found that between the time of their infection and the time of their first appearance for treatment these cases had exposed 134 other individuals by coitus, 442 through family life, 651 by occupational association—in all 1227 people. At least sixty new cases developed and only two were brought under treatment. This points out our course. In addition to instituting thorough treatment in those we find with syphilis, run down the sources of their infection and aim to get these individuals under treatment. Discover the contacts of our case if possible and examine them thoroughly. The industrial physician has the opportunity offered few others of doing efficient and valuable public health service.

What should constitute thorough treatment? We have at Rush Medical College in Chicago a large clinic for the treatment of syphilis. Here we have tried to treat syphilis as efficiently as our modern methods will permit. Arsphenamine intravenously and mercury intramuscularly are our weapons. The course of treatment consists of six injections of arsphenamine at five day intervals. Between each injection of arsphenamine, one or two injections of mercury are given intramuscularly. After completing the six arsphenamine injections about fifteen or twenty injections of mercury are given three times a week, or at five day intervals, depending upon the salt of mercury used. This constitutes one course of treatment. The patient, after completing this, rests six weeks, and then a Wassermann is done. If the findings are still positive the course is given again. If negative, he rests for three months before another blood test is made. If positive then, another course is given. If at the end of two years his blood and spinal fluid are found negative, and, by repeated examinations, he has shown no sign of lues, he is discharged as cured. It should be impressed upon the patient time and again that he is not to discontinue treatment until he is told to do so by his physician.

It has been found from experience that very few patients will refuse treatment once they have their condition carefully explained to them. A good confidential talk will convince even the most ignorant and skeptical of the necessity of taking thorough treatment. Sometimes patients become a little careless about reporting after their sufferings have been alleviated, but through our social workers we keep in touch with them, and constantly remind them of their duty to their families and to themselves.

The cost of treatment is the thing that keeps most patients from taking care of themselves. With the cost of living exorbitant as it is, the average man with a family and a monthly wage of $150 or less, has a hard enough time paying for the bare necessities of life, without thinking of incurring doctors' bills for a disease that is not bothering him appreciably. Pay clinics are the solution for this problem. Clinics which will permit people of the middle class to obtain expert medical care for a small sum.

If we are to eradicate syphilis, and that is the question of the hour, we must, by all means, treat the existing cases of it first. These are our source of infection. In Chicago, we have been fortunate in having a large venereal clinic in connection with our industrial medical and surgical clinic. There all cases referred from the various industries are treated free of charge, or at a very small cost. Other industries will not be so fortunate in being located near a clinic. In the very near future, however, they may be aided by the Public Health Service. The number of clinics being operated solely by the Public Health Service now is twenty-six, in co-operation with state boards of health, 134. The number of clinics is being rapidly increased and it is believed that within a short time no industrial community will be without one. If an industry is not located so that recourse can be had to one of these, the staff can readily establish one where arsphenamine and mercury can be given at a very slight cost to those employees who, through financial reasons, are unable to consult specialists. Eliminate the financial question and all infected employees will only be too glad to take care of themselves. Once this is done efficiency is bound to increase.

Industrial physicians, the public health servants of their own communities, should encourage the building of hospitals for the treatment of venereal diseases. The number of hospitals equipped for and willing to treat acute syphilis is very small even in our large cities. The army

method of treating acute gonorrhea and syphilis at the base hospital, by keeping the patient in bed, and in a way quarantined, is a rational method of treating these diseases. It is only by keeping the acute cases under constant surveillance and from association with the world at large that we can hope to eradicate successfully the source of infection. For that reason, industrial physicians must work for the establishment of hospital wards in all hospitals, for this treatment. This will mean a big step in helping to eradicate the disease.

By following out some such scheme as has been indicated in this article, industrial physicians can play a large and important part in this campaign against syphilis, an inestimable factor in industrial inefficiency.

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INDUSTRIAL MEDICINE AND SURGERY—A RÉSUMÉ OF ITS DEVELOPMENT, SCOPE AND BENEFITS *

PART II

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THE United States is now entering the period of reconstruction following the great World War. Vast changes in the economic and industrial forces of the country are bound to occur. This nation, which entered the world conflict in order to make the world safe for democracy, will demand a truer, more just democracy at home. Misuse of political and economic power will not be tolerated, but all things which tend to give peace, comfort and contentment to our people—a true social democracy—will be exceedingly welcome.

The present labor unrest in Europe has already caused a reflex in this country, enhancing to a degree the unrest which was more or less prevalent. Both capital and labor recognize that the cure for this undercurrent of dissatisfaction is the reestablishment of a closer relationship, a better understanding, between the employer and those employed.

The cure for Bolshevism is a true democracy for all. Such a democracy can only exist when all our people have proper living conditions; a working day which allows sufficient time for the recuperation of the bodily forces, instead of the long hours of labor with no time for pleasure and relaxation; opportunity for education and development for the children, instead of the nation's shame—child labor; protection from exploitation of the women who must work; in fact, a spirit of justice and unselfishness among the employers, which will engender a spirit of loyalty and contentment among the employees.

The signs of the time indicate that during this period of reconstruction industry will solve many of these problems, and that both the employer and the employed will join hands in a mutual interest, with a better understanding than has ever existed before. Many forces are at work in industry to accomplish this end. One need only read the programs during the last three years of four national associations—the Employment Managers' Association, the National Industrial Engineers' Association, the National Safety Council, and the American Association of Industrial Physicians and Surgeons—to observe these signs. The members of these associations and of similar organizations, employed in hundreds of the great industrial concerns throughout the land, represent the leaven constantly at work to make possible the ideals of a true social democracy.

The very foundation of all these efforts is *better health,* the protection from occupational diseases and from accidents—*the conservation of the nation's man-power.*

Industrial medicine and surgery embody all phases of this human maintenance service, and are intimately connected with all other branches of employees' relations. The industrial physician who neglects the questions of hours of labor and of wages, the relationship between managers and foremen and the men and women under them, the living and home conditions of the employees, the food, the recreation and the general environment of each individual on the working force, will not attain the full purpose of a medical service in industry.

To reiterate†, the scope of Industrial Medicine includes:

A. Plant sanitation.
B. Prevention of occupational diseases.
C. Prevention of accidents.
D. Health supervision of employees, by:
    1. Physical examination.
    2. Examination of applicants.
    3. Educational propaganda.
    4. Protection against contagious diseases.
E. Surgical care of all injured.
F. Supervision of medical treatment, or, as is

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†See Industrial Medicine and Surgery, Part I, THE JOURNAL OF INDUSTRIAL HYGIENE, 1919, 1, 1.

done in a few concerns, rendering complete medical care.
G. Complete care in certain diseases, as tuberculosis, syphilis.
H. Visiting nurses' service to sick employees.
I. Improvement of home conditions.
J. Improvement of community conditions.
K. Co-ordination and co-operation with all forms of welfare service in industry.

No system of industrial medicine is comprehensive that does not include the ramifications of the above general phases in its scope.

To-day, with the profession on familiar terms with industrial medicine; with at least six medical schools teaching some phase of the work; with state and federal legislation embodying its principles, it can truthfully be affirmed that this new specialty in our profession—Industrial Medicine and Surgery—has arrived and is now firmly planted in the economic structure of the nation.

This résumé of the new development and the scope of industrial medicine leads us to this important consideration: Does it pay? From an economic viewpoint, what is its value to industry?

One of the greatest sources of saving to the employer is the physical selection of employees for work. *This is done by the physical examination of all applicants for work before employment.* The value to the employer depends upon the thoroughness of these examinations and the amount of co-operation between the employment department, the medical department and the foreman.

The old system in vogue before medical examinations of employees was introduced into industry, and which still exists in so many places, resulted in wasteful occurrences such as the following:

1. A man applied to the employment department or to the foreman for a job. He had had words with his foreman in another industry and had left. (This was the result of less and less work due to a physical handicap of which he was not aware.) Experience made him valuable for certain types of work. He was employed and thrown into the human machinery of this new industry without any investigation as to his physical fitness. His work was on a machine and was very heavy. He exerted himself to make good and at first succeeded, but gradually the production of his machine fell behind, and after two months the foreman was forced to let this man go. For two months an expensive machine had failed to produce sufficiently to pay for its maintenance—a definite loss for the employer. And why? Because this man who was employed blindly had a beginning locomotor ataxia and was physically unable to make good. An examination when he applied would have prevented his employment, saved the loss from inefficient operation of the machine, and the cost of hiring and firing a man.

2. A laborer was employed by an electrical company. Their medical staff did not include medical examination of applicants as a part of their work. Therefore, without ascertaining his fitness, this laborer was assigned to help repair boilers. Two weeks after employment, while working in a boiler, he dropped dead. A nearby electric light was broken when he fell. A shyster lawyer persuaded his family that the man's death was due to an electrical shock, and suit was entered against the company. The autopsy immediately after the man's death showed an old chronic heart lesión, and death was recorded as due to acute dilatation of the heart. There was no sign of an electrical burn. When the case appeared before the Industrial Commission the family was awarded $3,500. Naturally the company carried the case to court, and after a long fight they were absolved of all responsibility for the man's death. The expense of employing expert witnesses, legal talent, etc., was very heavy. This blind hiring of a defective human machine cost this company over $5,000 for two weeks of service.

The placing of all comers on jobs without any effort at a physical selection for their work is responsible for a great financial waste which cannot be shown in dollars and cents, but which, nevertheless, is very evident. Some of the sources of waste from the employment of the physically unfit are the following:

A. The unfit who later must be discharged because of inability to do the work.

B. The unfit who may continue to work for a few months or a year, but with a gradual decrease in their efficiency, due to advancing disease. Sooner or later they are forced to stop work, and during the entire period of employment they have been a source of loss to the company employing them.

C. Those who because of their physical condition are subject to frequent accidents.

D. Those who suffer accidents which ordinarily would not be serious, but, because of coincidental physical conditions, cause prolonged disability or even death.

E. Those having some contagious disease when employed, who communicate it to others in the working force. The acute contagious diseases are more common, but tuberculosis and syphilis also cause a great loss.

F. Employment of the mentally deficient, the moral degenerate, and other types of mentally handicapped men who make up a certain percentage of the floating labor. An observing industrial physi-

cian will pick out this type during the course of his examination.

Companies which have an efficient medical system always include the examination of applicants as a definite part of the work. These examinations are not made for the purpose of selecting only the physically fit and refusing employment to all others, but are made for the following purposes:

(a) To prevent persons with diseased conditions which make work of any kind dangerous to them, from going to work; (b) to select for persons with certain defects proper jobs where they can still be efficient and yet the work will not be hazardous to them; (c) to prevent persons with contagious diseases from mingling with the old working force.

The writer has collected statistics from ten large industries, having very excellent medical staffs, which examine all applicants for work. Their rejections are based, for the most part, on the above standards. The following table shows the results of these examinations:

1. Total number of applicants examined in one year	118,900
2. Total number employed having disabilities that did not interfere with selected work	41,158 or 34.7 per cent.
3. Total number rejected for work because of disabilities	11,433 or 9.7 per cent.
4. Total number having no disabilities of any moment	66,309 or 55.6 per cent.
5. Total number of regular employees in these ten industries	102,400

It is fair to assume that these 11,433 applicants who were rejected for work would have soon lost their positions because of inefficiency, or would have left because of sickness. Certainly by the end of a year practically all of these would have been eliminated from the working force. It is impossible to estimate accurately what the loss to these companies would have been during that year from having these men and women in their employ. It would have been considerable, however, from decreasing efficiency due to disease, from an increased accident rate, from loss of time due to sickness and the resulting sick benefits in many cases.

Several estimates have been made of the cost of labor turnover. These are based on the cost of employing a man, teaching him a job, and the time elapsing before he becomes efficient or productive. These estimates vary from $10 to $200. One authority, after a careful study of this problem in many industries, gives as a low average the amount of $35 as representing the cost of hiring and training an individual. Therefore, the 11,433 rejected cases in the above table can be estimated as saving the companies rejecting them $400,155 in labor turnover. A committee of representative authorities on this subject more recently estimated the cost of hiring and training a man at $45, which would add over $100,000 additional profit as a result of the practice of medical examination of applicants for employment.

Magnus Alexander in a comprehensive study of the cost of health supervision in ninety-nine different industries found that the average cost per employee for all medical work was $2.50. Using this figure as a fair average, and taking the regular number of employees as 102,400, we can estimate the cost of the entire medical work in these ten industries at $256,000. Thus the examination of applicants alone undoubtedly saved these companies over $140,000 during the course of one year.

1. Saving to ten concerns from rejection of physically unfit	$400,155
2. Cost of entire medical work in these concerns	256,000
3. Profit to the concerns from this one branch of medical work alone	$144,155

It is fair and conservative to estimate that at least 10 per cent. of those applicants with physical disabilities who were employed would have left very shortly if they had not been placed on jobs suitable for their physical condition, thus adding to their efficiency, contentment and health protection. This adds another $144,000 to the profit of the employers from this system.

While the above figures can only be estimated, yet the most skeptical must surely agree that the examination of applicants for work, and the rejection of the physically unfit, even when based on the most humane standards for rejection, certainly pays any concern adopting this system. And the saving to that concern from this procedure alone will more than pay the costs of the most efficient human maintenance department they can establish.

Epidemiology—prevention of the spread

of contagious and infectious diseases among the employees—has added tens of thousands of dollars to the net annual proceeds of the employer. The discovery of tuberculosis during the early stages of the disease and the elimination of employees suffering from it from the working force, has prevented other employees working in close contact with infected individuals from becoming infected. Fortunately most of the concerns practicing this form of protection likewise provide for the care of the afflicted employee, usually sending him to a sanitorium until the disease is arrested. In one industry, during a period of three years, twelve individuals with lip chancres were discovered during the examination of applicants. The menace of these cases thrown into the old working force is quite apparent, as is also the value to the employer in preventing the spread of this disease among the workmen.

In one large industry employing 15,000 people, in Chicago, forty-four contagious cases, representing six different types of the acute exanthemata, were discovered during a period of six months by the system of health supervision in operation in that plant. The early discovery of these diseases, and the constant watchfulness to prevent their becoming epidemic among the employees who were working in close contact, undoubtedly prevented a great loss to this concern from at least six different epidemics. This experience is a fair example of the extent of epidemiology in industry.

The managers of several industries have reported that the careful medical supervision and prompt attention given their employees by their medical staffs during the recent influenza epidemic resulted in a lower sick rate and a much lower death rate among their employees than among their subsidiary industries, where medical services were not maintained.

It is impossible to estimate in dollars and cents the benefits to both employers and to employees that have accrued from the prevention of accidents. Hundreds of industries, however, throughout the country are enthusiastic in their praise of this form of prevention. The prompt care of injury cases by competent industrial surgeons has reduced the period of lost time, the extent of deformities, the number of permanent disabilities, and many deaths. In large concerns where the accident rate is high, in spite of their preventive methods, the profits accruing from prompt, efficient surgical care are known to be far in excess of the cost of the entire medical service. The prevention of infections due to minor injuries in one concern caused a reduction of 70 per cent. in time loss after these preventive methods were installed.

Innumerable examples could be given of the benefits to both employer and employee resulting from the various branches of their industrial medical and surgical services. The ever-increasing number of industries that are adopting this form of medical service for their employees is the most conclusive evidence of its real value. Big business is not in the habit of adopting any type of welfare service that cannot pay its own way. Some employers, however, will see the human side of this work, while others, of a more calculating disposition, will look for the dollars and cents value before installing this system.

In those industries where pioneer work in industrial medicine and surgery has been done, the results should satisfy either of the above types of employers that such supervision pays dividends and makes a happier, more contented working force. It must be the duty, therefore, of every company surgeon, of every safety engineer, and of every so-called welfare worker, to show that *the benefits to the employer are in direct ratio to the thoroughness and completeness of the plan which he adopts for the conservation of the health of his employees.*

Very few employers, even in industries where various plans of health supervision have been inaugurated, realize the reasons therefor and the full significance of this work. If they would only comprehend the value of conserving the lives and limbs of their employees, a social evolution would occur which would react to the great welfare of both the employer and employee, and would solve more labor disputes in a minute than the old system could solve in a year.

PROTECTIVE GARMENTS IN THE WAR GAS INDUSTRY *

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ONE of the interesting medical demonstrations incident to the war, was the effectiveness of measures protecting operatives in the production and handling of the war gases in this country. So successful were these protective measures, that although hundreds of tons of war gases were being produced by processes entirely new, and in the hands of men quite inexperienced in these particular manufacturing problems, the fatalities attributable to the war gases could be numbered on the fingers of one hand, and the temporary casualties were proportionately small in number. And this, despite the remarkable toxicity of the substances produced, the raw materials used, and the tremendous urge of the emergency, demanding as it did almost any sacrifice in order to increase the rapidity of production.

In view of the lessons which may be drawn from this demonstration it may be of interest to analyze the elements of the situation which made possible this remarkable record.

In the first place, the toxicity of the products was well realized by all concerned in their production. The very fact that these substances were manufactured to produce death, advertised their dangerous character. In most cases the war gases were in effect far more deadly than hydrocyanic acid because of the cumulative character of their physiological effects. Thus while hydrocyanic acid at a certain concentration kills, it may be breathed at lower concentrations without injury. On the other hand phosgene, mustard, chlorpicrin, and other war gases produce a pathological effect at practically all concentrations. However low and temporarily harmless the gas concentration may be, if exposure to it is long enough, serious injury results. This peculiarity of the war gases may be roughly expressed by the equation *Time* $\times$ *Concentration* $=$ *Degree of Injury*. Knowledge of this fact gave special impetus to the development of protective measures, and also led to a degree of co-operation between operatives and inspectors and an appreciation of what was being done for safety that was exceedingly valuable.

In the second place, by the nature of the contracts made, control of the plants, operations, and personnel was on a military or semi-military basis. Effective measures for protection could be enforced. While it is difficult to evaluate this factor, it is certain that this discipline had much to do with reducing the number of casualties. What protective measures were decided on could be rigidly put into practice.

In the third place there was no false economy practiced. Since production was, in most instances, either directly by the government or on a cost-plus basis, it was not necessary to count too closely the financial cost of effective protection. It was assumed that *production* must be facilitated regardless of expense, and effective protection with good morale among the operatives, was absolutely essential to high-speed production.

In addition to these factors, each gas was studied from the point of view of its effect on the operatives, with a thoroughness, which has hardly been equalled in medical history. It is probable that the biological and medical aspects of phosgene, mustard and certain other gases is known in greater detail today than that of malaria, heat burns and other common diseases and injuries that have been observed and treated by medical science for generations. The conclusions and practical recommendations developed by this intensive study of the effect of these gases were immediately put into effect in the factories, regardless of cost or prejudice.

As an offset therefore to the fact that there was no experience in the manufacture of these substances to guide the producer, that there was, to begin with, no medical knowledge of symptoms, pathology, prognosis and prophylaxis, and that the gases themselves are the most effec-

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tively deadly substances ever handled, and that they were being handled by the ton or by the car load—as an offset to all this stood the fact that the degree of protection and the measures thought necessary could be dictated by the results of experimental study, carried on by large groups of trained investigators to a degree perhaps never before approached. The net result was therefore a highly satisfactory one, and protection of the workmen became an accomplished fact.

One small phase of the general program for protection was that afforded by special garments. It is probable that, had the war continued, other types of mechanical protection would have reached such perfection that the garments could have been eliminated entirely, except in certain highly exposed positions. Indeed before operations ceased this was already true of certain plants. Garment protection must therefore be considered as a temporary expedient, to be abandoned more or less completely as automatic machinery and standard practice made its use less necessary.

The need for highly specialized protective garments developed with the demand for the skin irritant gases like "mustard." This group of war gases is characterized by rapid penetration of the skin by either vapor or liquid, in addition to the effect on eyes and respiratory tract. The gas mask gave excellent protection to eyes and lungs, but the skin was injured as quickly through ordinary garments as where it was not covered. The skin lesions were so slow and insidious in their onset, and so slow in their healing, that it was realized how readily the entire personnel of a plant might be temporarily incapacitated by a single accident. To guard against this it became necessary to develop garments which would guarantee protection to a man in an atmosphere which would otherwise produce burns, or to discover some other way of insuring protection to his skin. Thus protective garments and ointments were studied and developed simultaneously, with reference both to the field of battle and to the factory.

The first problem for solution was the selection of the fabric and impregnators to be used. Rubber preparations were unsuitable except in short emergency situations because of the rapid penetration of rubber by "mustard." Rubber serves to hold the mustard as a reservoir near the skin and so may do more harm than good under certain conditions. Heavy rubber gloves and boots were used, but special precautions had to be taken for the demustardization of the rubber before the gloves or boots could be reissued for use. Certain types of the American oilcloth were found to offer fairly effective resistance to penetration by mustard. A very large variety of fabrics were made up and tested against both the liquid and vapor, and for these tests an elaborate procedure was developed in the Research and Medical Divisions of Chemical Warfare Service. Penetration of a fabric was tested both by chemical means and physiological—i. e., determinations were made of the time required for a standard weight of the liquid, applied to a standard area of the cloth, to penetrate sufficiently to cause a chemical indicator to react, or to cause a burn on human skin when the fabric was applied for a standard length of time. The details of these tests are not of general interest, since each type of substance to be tried demands its own particular procedure. The general result was that "slicker" material of good grade, such as could be obtained on the market in quantity, was found to offer considerable protection against mustard vapor, and a short protection against the liquid. Finer types of varnished oilcloths, made up by impregnating very close-woven fabrics, offered considerably more protection. Such cloth, free from pin holes, will keep out the vapor for hours, and the liquid for shorter periods, but long enough so that a man splashed with the liquid, or exposed in his work to high vapor concentrations, may still expect to be able to remove his contaminated garments, and escape unburned from a situation where ordinary clothing would be worse than useless.

Coverall suits were made up from such material and, while clumsy and fatiguing, could be worn by workmen in cool weather. In warm or hot weather such suits rapidly become almost intolerable, and would be discarded by average factory workmen. It was possible to keep men working in these suits in the gas factories by military discipline. These garments

were made up in large quantities and issued at the front and to gas factories.

An early modification of these suits was intended for use in the most dangerous and exposed situations. The coverall suit was combined with a light metal helmet and attached by a hose to an air line, so that fresh air was blown over the face of the wearer, keeping the window clear, ballooning out the suit, and escaping through the seams and about the shoes and gloves. Such a suit was in effect a diving outfit and would enable the wearer to work in almost any concentration of mustard, for any length of time. The air current kept the temperature down, allowing evaporation of the perspiration, and by its outward flow preventing any possible accumulation of gas inside. The use of this type of suit was limited, of course, to those portions of the plant to which compressed air pipes ran, and by the working radius of the air hose. The suits were valuable mainly in giving confidence that, should it be necessary to work in a highly dangerous situation, the operator could be certain of safety.

A modification of this idea was the coverall suit having a hood which could be tightly drawn about a man's face, with the gas mask in place, thus preventing entrance of gas, and insuring air for breathing free from gas. Such a combination offered greater latitude for working but was, of course, hot, and the field of vision was much more restricted, being that allowed by the eyepieces of the regular army mask only.

Neither of these suits had any considerable actual use. It is probable that the air-lined type, because of its greater comfort, more complete protection, and large field of vision, would have remained as a part of the permanent emergency equipment of mustard and similar plants, while the other type would have been discarded.

The garment largely issued for use in the plants was a coverall suit of slicker material. It could be tied at wrists and ankles, and was supplemented with protective shoes, and gloves, and masks when the latter were needed. These garments were removed after factory hours and were demustardized with chloride of lime, water, or by long airing, before reissue. No standard practice for removing mustard had been developed when operations ceased. These garments had a number of bad features. They were clumsy and heavy, excessively hot, and their life was short. Constant creasing or bending produced leaks. They were easily abraded, and any chlorinating method of removing mustard from them produced rapid deterioration. A constant supply of fresh garments was therefore required.

Another type of garment developed was made of open-mesh fabric, like porous underwear material, and was impregnated with substances which would absorb mustard. Such garments allowed transpiration of air and thus the evaporation of perspiration from the skin of the wearer, but would protect against mustard vapor for a limited time but not against liquid mustard. They were more comfortable and less clumsy than the oilcloth suits, but were heavy and disagreeable, at best.

Still another type of garment, which was being perfected when the war ceased, depended on the impregnation of the fabric with a hydrous gel through which the moisture of the skin could pass and evaporate, but which was impervious to mustard gas or liquid for a considerable time. While this garment was never given a factory trial, it promised to be a great improvement over the others. It too was rather heavy and, of course, rather hot. Its wearing qualities were never given an actual test under factory practice.

Garments and gloves were also made containing a layer of thin fabric or paper impregnated with a gum-glycerine gel and protected by layers of cloth on either side. This material actually stood up against liquid mustard for days without penetration, but it was very heavy, hot, and clumsy. It could have served as an impervious apron against splashes on the front of a man, but it was not suitable for a complete coverall garment.

One of the most difficult problems was the protection of the workmen's hands. The danger of vapor or splash burns on face or body was quickly reduced to the minimum in operating plants, but there was constant danger to the hands. Gloves of oilcloth as well as ordinary cotton gloves dipped in linseed impregnating mixtures, were tried. Such gloves were

quickly worn or creased to the point of being more a menace than a protection. Heavy rubber gloves were fairly good but allowed mustard to accumulate, dissolved in the rubber itself, and led to burns inside. The best gloves appeared to be those prepared by impregnating good-grade "splits" leather gloves such as were issued by the Quartermaster Department, with a carnauba wax and oil formula. Such gloves were more flexible than the oilcloth, wore far better, and could very easily be degreased and demustardized in gasoline and reimpregnated, if contact with mustard was suspected. The same wax-oil formula was used to impregnate leather shoes for service in mustard plants. Like the garments, the glove and shoe problem was still in the experimental stage when the manufacture of the war gases was discontinued.

From observations made during the manufacturing period of the war, the author is inclined to believe that protective garments, gloves, masks, etc., can be used to great advantage in industries where the production of highly toxic or irritating vapors is unavoidable. Garment protection, however, should be considered only as a temporary measure of protection or as valuable in emergencies or particularly dangerous situations. It is doubtful whether workmen can be expected to undergo the discomforts and fatigue incident to prolonged wearing of such garments as have been described above, or whether they would continue in employments where such garments were prescribed. Much can be done undoubtedly to lighten the weight and increase the comfort of protective garments, provided research is concentrated on the problem. Without great improvement, it is not believed that this solution of the protective problem is largely applicable to peace time industries.

BOOK REVIEWS

The Physiology of Industrial Organization and the Re-employment of the Disabled. By Professor Jules Amar, Director of the Laboratory of Physiological Research in the Conservatoire des Arts et Métiers, Paris, France. Translated by Bernard Miall. Edited with notes and an introduction by Professor A. F. Stanley Kent, M.A., D.Sc., Oxon. Pp. 371, with illustrations. London: The Library Press, Ltd., 26 Portugal St., W. C., 1918. New York: The Macmillan Company.

The English translation of Professor Amar's book reaches the United States at a fortunate time. We are receptive toward efforts at exact measurement of working capacity as we have never been before.

The book represents a determined and often very ingenious effort to apply well-known physiological methods for the measurement of work in the simpler animal preparations of the laboratory to working conditions in human beings.

There is an opening chapter dealing with the history of efforts at exact physical evaluation of labor and ending in a brief discussion of the Taylor system of scientific management, of which the just physiological criticism is offered that "like La Hire, Amantons, and Coulomb, Taylor considered only a part of the human machine—that which performs work." He neglects the physiological limitations of this machine and so, without modification, his system cannot spell success. It would seem that no system could be more foreign to the French genius than that of Taylor, which must inevitably tend to subordinate the individuality of the worker to the exact dictates of mathematical direction. One feels, perhaps, that Professor Amar as well as Professor Kent in his introduction is under a false impression as to the extent to which what may be called literal Taylorism exists at the present time in the United States. Foreign writers would do well to recognize the scientific management developed by Taylor as a decided influence in American industrial organization but not as a successful rule of conduct for the entire country.

Professor Amar introduces his own work in industrial physiology by a chapter on the Organic Functions of Man, and follows this with another on Human Psycho-Physiology. It is rather noteworthy that the contributions upon which this applied physiology is apparently based are practically entirely French and German. It is hardly possible to treat the physiology of the nervous system without rather thorough dependence on English contributions to the subject.

Under Work and Fatigue, the Factors of Labour, and the Art of Labour, Amar presents his real contributions to industrial physiology. Making use of Marey's tambours and a variety of ingenious additional appliances, measurements have been made of such familiar types of work as planing, filing, shoveling, etc. These studies serve as aids for standardizing such processes in terms of the minimum necessary effort for accomplishment of the task in question. Qualitative differences in the curves secured indicate the smooth and regular worker as opposed to the irregular and less efficient beginner. Such curves may eventually find usefulness in checking up the rate of training or condition of efficiency of the apprentice.

Final chapters in the book deal with Re-Education of War Cripples. Here again Professor Amar makes effort at exact physical analysis of the tasks to be fulfilled, and attempts to create artificial limbs in accordance with the true mechanical requirements of the case in question. As in the earlier chapters of the book, both the final artificial appliances evolved and the methods used in measuring their efficiency are thoroughly illustrated and give one a working idea of the efforts Professor Amar has made.

The book is a pioneer in a field which will have much attention during the next decade. It pictures a courageous attempt to measure the almost immeasurable and deserves the thorough consideration of all those interested in the most modern efforts at evaluation of labor.—*Cecil K. Drinker.*

The Science of Labour and Its Organization. By Josepha Ioteyko, formerly head of the Laboratory of Psycho-Physiology at Brussels University, Laureate of the Institute and of the Academy of Medicine, in charge of the course on "Fatigue" at the Collège de France in 1916. Pp. 199, with illustrations. London: George Routledge & Sons, Ltd.; New York: E. P. Dutton & Company, 1919.

This small volume presents a series of articles written during the years 1916 and 1917. The reader will find difficulty in following any consistent theme through the whole presentation and should accept the book as a set of essays relating more or less directly to industrial problems.

The first two chapters on The Human Motor and The Principles of Scientific Management are quite useful summaries in the first instance of organized continental effort for study of industrial fatigue, and in the second of scientific management. This latter chapter defines the physiological limitations of Taylor's system in a thoroughly useful manner. The third chapter, on the Power and Aptitude for Work, concerns itself chiefly with the author's views on right-handedness and the advantages of bi-manualism. It is rather hard to conceive that the benefits of ambidexterity can be of so wide importance as Ioteyko represents. The book closes with an account of the Belgian methods of education for industry, and is, on the whole, a useful reprint of material not readily available for English and American readers.—*Cecil K. Drinker.*

NINTH CONFERENCE OF INDUSTRIAL PHYSICIANS AND SURGEONS

The ninth conference of industrial physicians and surgeons will be held at the Hall of the House of Representatives, Harrisburg, Pa., on Monday, Sept. 22, 1919, under the direction of the Division of Industrial Hygiene and Engineering of the Bureau of Inspection of the Department of Labor and Industry, of Pennsylvania. For particulars, address Dr. Francis D. Patterson, Chief, Division of Industrial Hygiene, Department of Labor and Industry, Harrisburg, Pa.

SIXTH ANNUAL MEETING OF THE INTERNATIONAL ASSOCIATION OF INDUSTRIAL ACCIDENT BOARDS AND COMMISSIONS

The sixth annual meeting of the International Association of Industrial Accident Boards and Commissions will be held in Toronto, Canada, Sept. 23-26, 1919. For particulars, address the Secretary-Treasurer, Royal Meeker, Commissioner of Labor Statistics, Washington, D.C.

EIGHTH ANNUAL SAFETY CONGRESS

The eighth annual Safety Congress will be held at Cleveland, Ohio, October 1-4, 1919. For particulars, address the Secretary of the National Safety Council, 168 North Michigan Avenue, Chicago, Ill.

AMERICAN PUBLIC HEALTH ASSOCIATION TO MEET IN NEW ORLEANS

The next annual meeting of the American Public Health Association is to be held at New Orleans, La., October 27-30 inclusive. The central themes of discussion will be Southern health problems, including malaria, typhoid fever, hookworm, soil pollution and the privy, etc.

The general belief among the health profession is that influenza will return next winter, and a full session will therefore be devoted to this subject for the purpose of developing methods of control.

A special effort has been made to arrange the program to meet the practical needs of health officials. Accordingly there will be discussion on such questions as the attitude of legislators toward public health, the obtaining of appropriations, co-operation from women's clubs, health organizations, etc., the organization of health centers, and so on.

The programs of the sections will, as usual, deal with public health administration, vital statistics, sanitary engineering, laboratory methods, industrial hygiene, sociology and food and drugs.

Two special programs will also be presented on various phases of child hygiene and personal hygiene.

Winter railroad rates to New Orleans will be in effect from all points after October 1.

The program of the meetings will be published in the American Journal of Public Health appearing October 5 or may at that time be had upon application to the Secretary, 169 Massachusetts Avenue, Boston, Mass.